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DEVOTED TO

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Vol. CXXVII.

INDEX.

A COMPARISON OF VARIOUS CUPOLAS.

Designating Number.	Kind and Location of Cupola.	Dimensions of the Cupolas. Useful Height.	Diameter of the Shaft.	Diameter at the Zone of Fusion.	Tuyeres. Number.	Diameter in Inches.	Charges. Iron per Charge.	Coke per Charge	Pressure of Blast in Inches of Water.	Consumption of Coke. For Melting.	Total.	Mean Product per Hour in Tons.	Remarks.
		Inches.	*Inches.*	*Inches.*			*Pounds.*	*Pounds.*		*Per Cent.*	*Per Cent.*		
1	Royal Foundry at Gleiwitz,	86·61	24·8 to 30·7	. . .	2	. . .	330·71	85·98	. . .	20·0	27·7	. . .	From Le Calendrier Allemand *Hütte*.
2	Royal Foundry at Berlin,	. . .	24 8	. . .	4	1 57	275·58	44·09	. . .	16·0	22·0	. . .	
3	K. Marienhütte Zwickau,	120·86	31 49	. . .	2	4·64	606·29	99·21	. . .	16 4	19·2	2·0	
4	K. Marienhütte Zwickau,	110·23	48·81	. . .	3	4 64	1047 14	165·35	. . .	15 8	18 0	3·0	
5	Hungary works,	177·16	39·37	35·43	4 + 4	3·93	1102 36	176·37	. . .	15·3	17·02	. . .	
6	Magdeburg works,	86·61	37 00	. . .	. . .	. . .	661·42	58·42	. . .	8·83	15·00	2·75	From *Hütte*.
7	Ireland, cupola at Hörde,	185·43	43 30	. . .	4 + 8	. . .	1102·36	143 30	. . .	13·0	14·0	. . .	
8	Gerhardi (Ireland),	123·41	37 79	. . .	4 + 8	{2·67 / 5·11}	511·18	55·11	15·74	10·0	13·5	2·4	
9	Portable cupola at Saint Gervais,	66·14	{13 38 / 5·40}	10·42	3	2·55 — 2·75	110·23	13·22	. . .	. . .	13·48	. . .	According to M. Maillard.
10	Ireland at Borsig's works,	145·90	37 00	. . .	4 + 8	. . .	1653·55	110·23	. . .	5 to 7·5	13·0	. . .	According to *Hütte*.
11	Krigar, at Zwickau,	181 10	37 00	. . .	. . .	. . .	1102·36	92·59	. . .	8·4	13 0	. . .	
12	Krigar, in Prussia,	122·04	31 49	23 62	2	15 74 / 1·07	220 47	13 22	19·68	6·5	13 0	2·0	According to M. Fehland.
13	Krigar, in Silesia,	161·42	30 89	30·84	4	6·18	1047·24	77·16	17·71	7·4	13 0	2·7 to 4 0	
14	Krigar,	137·79	20 47	19 68	2	14·17 / 3·97	. . .	. . .	. . .	6 0	13·0	. . .	According to M. Kerpély.
15	Ireland, at Britannia Foundry,	146·06	45 00	27·00	20	. . .	2240 00	167·56	. . .	8·0 to 9·0	10· to 12·	6·1	
16	Krigar, in Westphalia,	145·67	43·30	29·13	1	. . .	1102·36	79·37	9·84	7 2	12·0	5 5	According to M. Fehland.
17	Voisin,	179·12	35·43	. . .	4 + 4	. . .	. . .	. . .	9·05	8·0	11·0	. . .	
18	Nevers Foundry,	129·92	{17 71 / 29 52}	18·89	6	5·51	661 42	46·29	6 49	6·26	10·63	1·35	According to M. Maillard.
19	Foundry at Saint Gervais,	140·67	{25 59 / 46·45}	32·28	6	7·87	1763·78	123·46	. . .	5·71	11·28	. . .	
20	Krigar, at a works in Saxony,	144·40	27·40	29.52	3 + 6	0 62 and 0·27	2204·73	160·94	. . .	7·3	9·8	. . .	According to *Hütte*.
21	Woodward, at Liverpool,	150·00	29·92	27 16	4 + 8	{7·00 / 2·99} — 1·96	1102 36	55·11	. . .	5·0	8·12	. . .	8·12 per cent appears to us a little exaggerated.
22	Ibbruger, at Gleiwitz,	. . .	. . .	. . .	36	. . .	661·42	55·11	24·40	. . .	10·0	. . .	*Dingler's Polyt. Journal.*
23	Sheffield, hot-blast,	444 09	{48·03 / 53·93}	48·03	4 + 4	. . .	1102·36	169·76	. . .	6·0 to 7·0	. . .	. . .	
24	Gmelin, at Budapest,	157·48	33 46	33 46	2	7·87	. . .	. . .	14·75	7·5	. . .	4·8	
25	Voisin, at Pompey, I	159 44	{35 43 / 37 79}	{37·79 / 25 98}	4 + 4	3·14 — 1·96	Large fragments.		. . .	9·5	11·0	3·0	
26	Voisin, at Pompey, II	159·44	{27 55 / 29 52}	{29·52 / 21·65}	4 + 4	3·14 — 1·96	. . .	. . .	. . .	7·5	9·0	2·5 to 2 8	
27	Angers, Ecole des Arts et Métiers,	157·48	23·62	18 89	4 + 4	{2·75 / 2·75} — 2·16	1102·36	55·11	8·66	. . .	9·3	4·0	
28	Herbertz, at Cologne, a	140·15	35·43	27·55	1	{2 *Tyr.* = 94·48 / *h* = 0·59 — 0·78}	1102·36	138·89	— 2·55	10·4	12·7	. . .	According to *Stahl und Eisen*.
29	Herbertz, at Cologne, b	140·15	35·43	27·55	1	. . .	1102·36	55·11	— 2·55	5·0	9·9	. . .	
30	Common cupola at Chisnyoviz,	141·73	27·55	27·55	2	{8 45 / 7·48}	992·13	99·21	. . .	9·46	12·28	. . .	
31	Greiner & Erpf at Chisnyoviz,	141·73	27·55	27·55	2 + 11	{8·45 / 7 48} — 0·98	992·13	27·55	. . .	2·8	6·27	. . .	
32	Greiner & Erpf at Budapest,	. . .	33 46	. . .	4 + 15	. . .	881·89	35·27	. . .	3·88	6·68	. . .	Certificates of these establishments.
33	Greiner & Erpf at Prague,	. . .	31·49	. . .	4 + 4 + 15	. . .	881·89	35·27	. . .	3·95	5·97	. . .	

(*Durfee.*)

Pressure of Blast in Inches of Water.	Consumption of Coke. For Melting.	Consumption of Coke. Total.	Mean Product per Hour in Tons.	Remarks.
	Per Cent.	*Per Cent.*		
...	20·0	27·7	...	From Le Calendrier Allemand *Hütte.*
...	16·0	22·0	...	
...	16·4	19·2	2·0	
...	15·8	18·0	3·0	
...	15·3	17·02	...	
...	8·83	15·00	2·75	From *Hütte.*
...	13·0	14·0	...	
15·74	10·0	13·5	2·4	
...	...	13·48	...	According to M. Maillard.
...	5 to 7·5	13·0	...	According to *Hütte.*
...	8·4	13·0	...	
19·68	6·5	13·0	2·0	According to M. Fehland.
17·71	7·4	13·0	2·7 to 4·0	
...	6·0	13·0	...	According to M. Kerpély.
...	8·0 to 9·0	10· to 12·	6·1	
9·84	7·2	12·0	5·5	According to M. Fehland.
9·05	8·0	11·0	...	
6·49	6·26	10·63	1·35	According to M. Maillard.
...	5·71	11·28	...	
...	7·3	9·8	...	According to *Hütte.*
...	5·0	8·12	...	8·12 per cent. appears to us a little exaggerated.
24·40	...	10·0	...	*Dingler's Polyt. Journal.*
...	6·0 to 7·0	...	...	
14·75	7·5	...	4·8	
...	9·5	11·0	3·0	
...	7·5	9·0	2·5 to 2·8	
8·66	...	9·3	4·0	
— 2·55	10·4	12·7	...	According to *Stahl und Eisen.*
— 2·55	5·0	9·9	...	
...	9·46	12·28	...	
...	2·8	6·27	...	
...	3·88	6·68	..	Certificates of these establishments.
...	3·95	5·97	...	

JOURNAL

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FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVII. JANUARY, 1889. NO. 1.

AN INVESTIGATION OF THE CONSTRUCTION OF THE VARIOUS KINDS OF CUPOLAS THAT HAVE BEEN USED FOR THE MELTING OF PIG-IRON.

BY M. A. GOUVY, JR.*

Translated by W. F. Durfee, Engineer.

(*Continued from Vol. cxxvi, page 447.*)

V.

CUPOLAS HAVING SUCTION BLAST.

Long before the steam ejector was invented, natural draft had been tried, but the melting capacity of the cupolas to which it had been applied was very small; there being a

* Étude sur les cubilots pour la fusion de la fonte. Par M. A. Gouvy Fils," published in "Mémoires et compte rendu des travaux de la Société des Ingénieurs Civils." Paris, 1887. pp. 723–766.

considerable loss of heat, because the time required to attain the melting heat of iron was relatively long, and the quantity of air supplied simply by the draft was very limited.

As early as 1855, Kerl speaks of a natural draft cupola at *Zintgraff;* more recently *Heaton* erected at Langley Mills a cupola on the same system, and in 1865 *Canhon* obtained a patent for an analogous construction; all these cupolas have been abandoned for the reasons above given.

Sir R. Mallet, in an article written in 1871,* speaking of the Heaton cupola, makes the following critical remarks, which we regard as very just:

"That this apparatus will melt iron is evident, if sufficient time is allowed to obtain the necessary heat." * * * "This furnace may be well suited to the Heaton process, in which the demand for iron is regular, and in some degree continuous; but it is not good for anything in a foundry."

The employment of a jet of steam to force the draft is subject to only a part of the objections to the foregoing methods; and the *Woodward* cupola, patented in 1865, does not embody all the advantages that we desire.

The Woodward Cupola.—This cupola, *Fig. 22*, was furnished with two rows of tuyeres; the upper row was the smaller and intended for lighting the cupola, being closed during ordinary work, but were opened in case it was desired to obtain the greatest possible product. The suction was produced at the centre of the neck of the cupola, by a jet of steam in a chimney of sheet-iron. The pressure of the steam used varied from forty-five to fifty-five pounds per square inch. The charge was introduced by means of a lateral hopper.

Sir R. Mallet, in the article already cited, speaks very unfavorably of this system, saying:

"There will be required a high pressure boiler, without a steam engine; but a low pressure boiler and a fan, driven by a steam engine, will produce the same results with much greater ease."

This criticism is a little exaggerated, as it is not really

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* *Practical Mechanics Journal*, 3d series, vol. 5.

necessary to have a pressure beyond forty-five to fifty-five pounds, and the absence of a steam engine is an important advantage when considered with reference to the first cost of an establishment and its subsequent maintenance; finally, we can regulate the draft at pleasure by modifying the dimensions of the ejector and the admission of steam thereto.

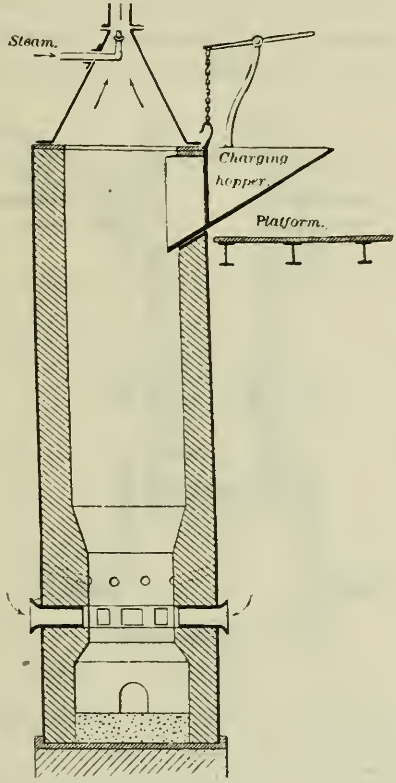


FIG. 22. The Woodward Cupola.

As regards the consumption of fuel, the Woodward system has given variable results, which may properly be attributed to the different dimensions of the tuyeres, which were generally too small, and also to incomplete combustion due to an irregular distribution of oxygen, as has been before said.

The Herbertz Cupola.—In the cupola, patented by M. Herbertz, of Cologne, at the commencement of this year (1887), (*Fig. 23*), the first of the disadvantages inherent to all the old systems in which high pressure blast, with very contracted tuyeres, was employed, is overcome, since we can augment at pleasure the area of the annular tuyere; but the second still remains. This cupola, when compared with those which precede it, is found to be in reality a combination of the systems of Woodward and McKenzie, with a slight improvement by which the annular aperture which

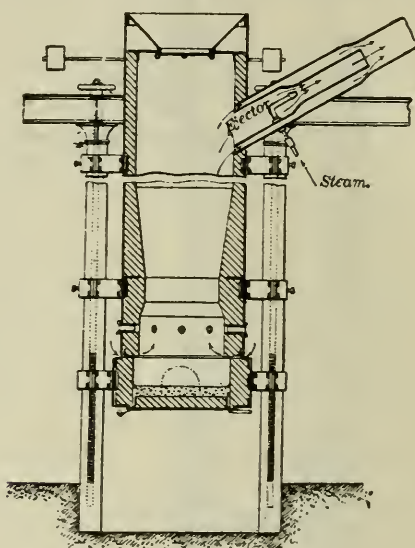


Fig. 23. The Herbertz Cupola.

replaces the tuyeres can be varied in height, by raising the crucible by means of the fixed screws.

The consumption of steam * for creating a draft, amounted to 204 pounds per hour, with an ejector whose diameter was four-tenths of an inch; in case a Root blower (requiring about three horse-power) were employed, the consumption of steam would be in the vicinity of 198 pounds; so there is not much economy in that direction. With

* *Stahl und Eisen*, No. 6, Juni, 1886, p. 399, and *Revue Industrielle*, Mai-Juin, 1886, p. 541.

regard to the consumption of fuel, the trials made in December, 1885, at Cologne, with a coke having three per cent. water and 6·8 per cent. ash, gave five per cent. of coke for melting, and 9·9 per cent altogether (this included the coke for lighting, the small coke recovered at the end the "heat" being deducted).

These results are evidently satisfactory, but do not very much exceed those attained in other cupolas in actual use in well managed works; the author of the article in *Stahl und Eisen*, shows for example the results of the Herbertz cupola, compared with those of Krigar and Ireland, and we now reproduce in part in the table below:

Trials.		Coke in Per Cent. of Iron.	
		For Melting.	Total.
1	Kreigar System having a detached crucible,	8·70	12·40
2	Kreigar System having a detached crucible,	6·32	16·70
3	Kreigar System having a detached crucible,	5·10	8·50
4	Kreigar System having a detached crucible,	6·70	9·10
5	Ireland,	12·00	18·70
6	Ireland,	13·20	14·70
7	Herbertz, first trial,	5·00	9·90
8	Herbertz, second trial,	10·20	12·70

From this we see that the results obtained by the Herbertz cupola do not compare very favorably with the other systems, while they themselves are far from the requirements of theory in their consumption of coke.

This circumstance is probably due to the pressure of blast being too feeble to allow the oxygen to penetrate the pores of the coke, as it would if the air were injected under a pressure of eight to twelve inches of water; the combustion being superficial and irregular, and also to the deviation of the currents of air drawn to the very short chimney by the steam aspirator, and finally to an excess of air as shown by analysis.

The gas from the tops of the cupolas of Krigar and Ireland is composed (in *volumes*) as follows, viz:

12·42 to 16·55 per cent. of CO^2
2·55 to 11·73 per cent. of CO
and 0 per cent. of oxygen; whereas in the Her-

bertz cupola we find, according to the author already cited:*

10·7 to 11·5 per cent. of CO^2

0 to 3·4 per cent. of CO

6·7 to 8·2 per cent. of oxygen, or 7·5 per cent. as an average.

Which means that in every 100 cubic feet of gas which traverses this cupola, there is

$$\frac{100 \times 7\cdot5}{21} = 37\cdot7$$

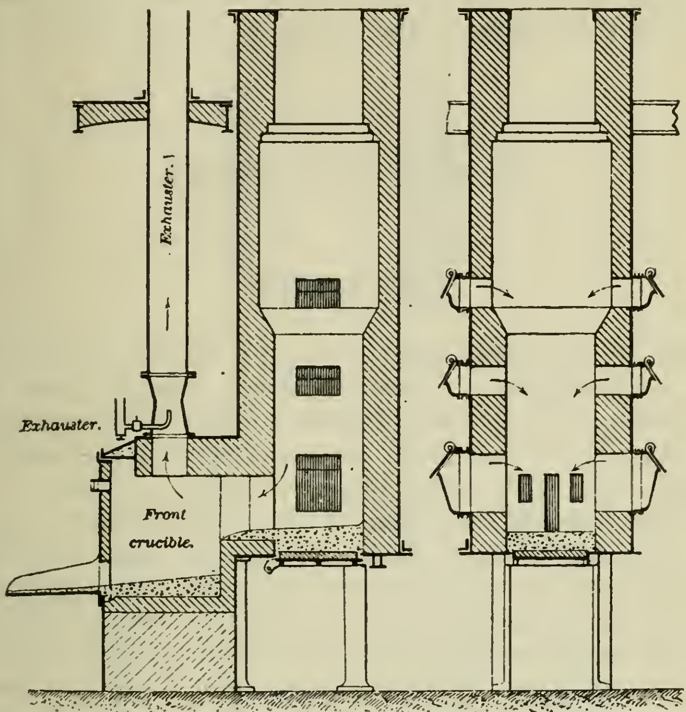
cubic feet of useless air drawn in, which must have carried off a notable quantity of heat, in addition to that lost by the escape of 2·55 to 11·73 per çent. of carbonic oxide not transformed into CO^2.

However, if we recognize the fact that for every 220 pounds of iron charged there is from 504 to 630 cubic feet of air used, we shall be able easily to account for the loss. We must add finally that the production is very small when compared with cupolas of the same diameter using a forced blast.

Krigar's cupola with forced draft.—In 1884, M. Krigar had also obtained a patent for a cupola having a detached crucible; this cupola was blown by a jet of steam placed over the detached crucible, which drew the air through large openings in the sides of the cupola, which were provided with regulating valves for directing the air toward the crucible, into which it was drawn, and from which it was forced by the ejector, which was placed in the small chimney before named (*Figs. 24* and *25*). The zone of fusion is therefore below the entrance of the air. In this system it is true that the gas is available for maintaining the heat of the iron gathered in the detached crucible, although the charge is not heated in advance of its arriving at the zone of fusion, but, on the contrary, it is traversed by the cold blast, and although we know nothing of the results which have been attained in practice, we believe that we are correct in saying that this cupola is far from realizing any economy in fuel; at its best it will not waste as much iron,

* *Stahl und Eisen*, No. 6, Juni, 1866.

and therefore there will be less decarburization, as the metal is not, as in the other systems, under the influence of an



FIGS. 24, 25. The Krigar Cupola with Forced Draught.

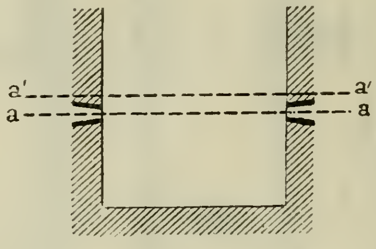
ascending current of air, and an atmosphere more or less oxidizing.

VI.

COMPLETE COMBUSTION OF THE CARBONIC OXIDE.

In all the systems which we have passed in review, the complete transformation of the coke into carbonic acid has received but secondary consideration ; whereas this is one of the most important conditions for economical melting, and it does not appear that we have taken sufficient account of the fundamental principles by which carbonic acid, when in contact with carbon heated to a red heat, gives up one-half of its oxygen and passes to the state of carbonic oxide.

In all cupolas having a single row of tuyeres placed from 27·5 to 31·5 inches above the bottom of the crucible, the carbonic acid resulting from the combustion of the coke in front of the tuyeres in the section *a*, *a*, encounters in the

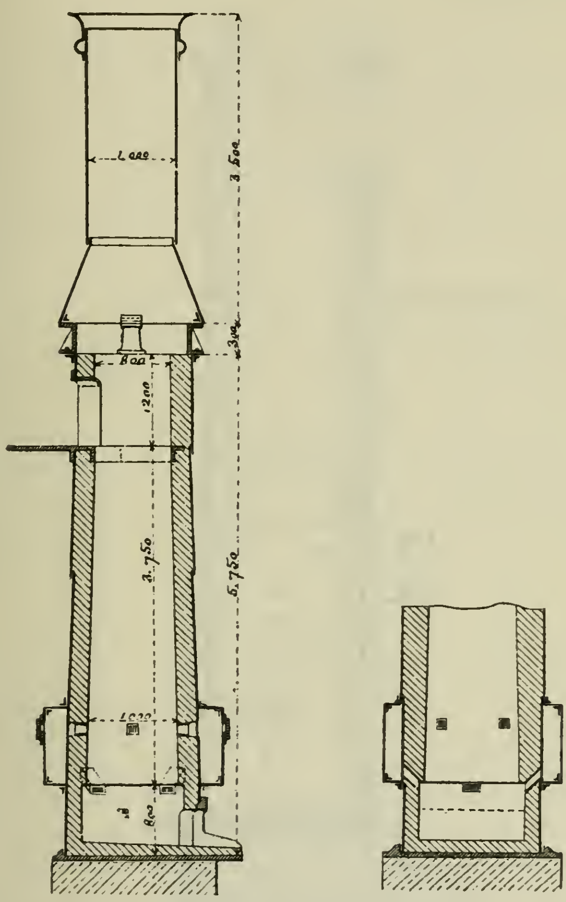


section a^1, a^1, immediately above, a layer of incandescent coke, and is nearly all transformed into carbonic oxide; and the carbonic oxide thus formed coming in contact with sufficient air (1 vol. of O for 1 vol. of CO), the result is carbonic acid with a development of heat.

If, for example, 2·2 pounds (1 kilo.) of coke, having eight per cent. ash, is transformed into carbonic acid, there will be developed 7,434 calories, and the same coke converted into carbonic oxide generates but 2,275 calories, being 5,159 calories less; it results that the system by which the largest part of the coke is transformed into CO^2 is the most advantageous, and approaches nearest to theoretical perfection, without regard to the fact that with the same sized cupola we are able to melt a very much greater quantity of iron per hour.

The Voisin Cupola.—M. Voisin appears to be one of the first to have given attention to this point; in some investigations for determining as exactly as possible the space above and below the axis of the tuyeres, occupied by the zone of fusion, he found that this zone extended at most but six inches in each direction. We are, therefore, easily able, by measuring the temperature at various heights, to ascertain the level at which the most carbonic oxide is formed, and it is at this level that M. Voisin places a second row of tuyeres, with the intention of re-forming carbonic acid and thus create a second zone of fusion.

With the Voisin cupola, illustrated by *Figs. 27* and *28*,* 100 pounds of iron were melted with eight pounds of coke, a result which has been augmented nearly twenty per cent.,



FIGS. 27, 28. The Voisin Cupola. Section through the Lower Tuyeres.

although the coke was of an inferior quality; the system is also very easy of application to existing cupolas.

The Angiers Cupola.—The cupola established at the Ecole des Arts et Metiers, at Angiers,* has an arrangement simi-

* Armengaud: *Publication Industrielle.* Vol. 22, p. 185.

lar (*Fig. 29*) to the Voisin cupola; the vertical section is somewhat different, as it presents a contraction above the upper row of tuyeres, whereas the preceding cupola is simply conical.*

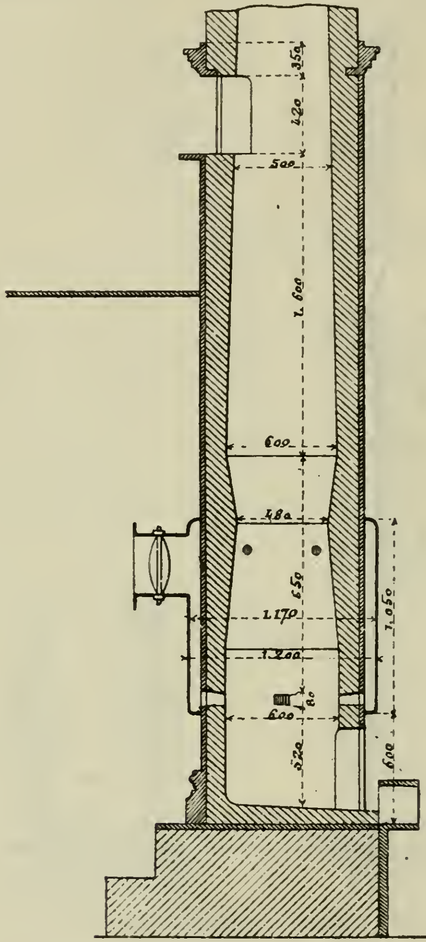


FIG. 29. The Cupola of the School at Angers.

The Angiers cupola has four tuyeres in each row; they are of a circular section 2·16 inches in diameter; the two rows are 25·6 inches apart.

* The profiles used for the Voisin cupola are not of necessity conical, as is indicated by the figures in the table annexed to this paper.

With a pressure of 8·66 inches of water they are able to melt 8,816 pounds of iron per hour, with a consumption of from 8·4 to 9·3 per cent. of an average quality of coke.

The Hamelius Cupola.—In 1880 M. Hamelius, of Paris, obtained a patent for a cupola analogous to the foregoing, with this difference: instead of the upper tuyeres having one common wind-box, they each received the wind through a vertical tube provided with a regulating valve; we also find the same arrangement in the Bichon cupola.

*The Stewart System.**—The Stewart cupola, of which we have often heard in recent years, and which is still in use in England, is said to be an improvement on the Voisin system, because it is furnished with three rows of tuyeres, of which the upper row is provided with regulating valves.

Stewart constructed this cupola with and without a detached crucible in front, and also in certain cases made the detached crucible movable on rails.

A special arrangement allowed the hot air of the crucible to be brought into the wind-box, and by an inverted injector cold air was blown into the crucible for the purpose of refining the iron.

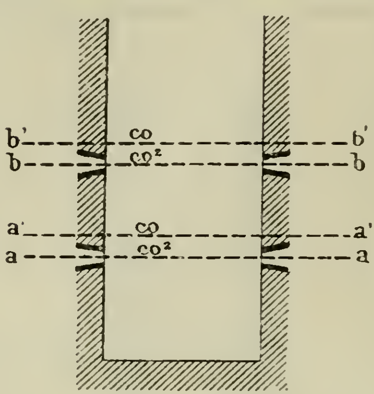
DETERMINATION OF THE NEUTRAL ZONE.

Now when we consider that *theoretically* the melting of 100 pounds of iron with coke having eight per cent. of ash, the coke being all consumed to carbonic acid, requires but four pounds of coke (in case the coke is simply transformed into carbonic oxide there will be required 13·33 pounds), we see that furnaces, having two rows of tuyeres, and which consume from six to twenty-five per cent. of coke for melting (not counting the coke used for "the bed") do not possess all the requirements of perfect cupolas.

It is obvious that the coke above the tuyeres *b b*, in the section *b′ b′*, bears the same relation to the CO^2 produced in *b b*, as the coke in the section *a′ a′* holds with regard to the carbonic acid developed in the section *a a*, although the quantity of carbonic acid produced at *b b* is less than at *a a*,

* *Engineering*, 1884, p. 56.

for the reason that the tuyeres *b b* are much smaller than those at *a a;* the temperature is, therefore, lower and the



zone of fusion less extended. It is for this reason that we always obtain in the space above *b b*, a certain quantity of CO which escapes at the throat of the cupola.

It is not, however, necessary that the descending materials attain the temperature of the incandescent coke, but only that the ascending gases are hot enough to take fire when in contact with the air. If, therefore, we introduced air by tuyeres above the zone of fusion *b b*, last established, we shall consume the carbonic oxide; but it is in this case very difficult to determine with precision the proper position of a third row of tuyeres in the same horizontal plane, so much the more from the fact that the materials do not always descend in parallel layers, thus permitting the concentration of the combustion of the gas in one plane, and elevating rapidly the temperature of the coke to incandescence, so that a reduction of the carbonic acid will be again possible.

We arrive, therefore, naturally at a new solution, consisting of an arrangement of a series of tuyeres, intended to serve the zone described (which we may call the *neutral zone*), not in one plane, but in a curve embracing a certain height of the cupola.

The Norris System.—This arrangement was already used in a very primitive fashion in 1855, and probably without

a knowledge of the advantages which we are now able to realize by its judicious employment. B. Kerl* mentions a Norris cupola "with a profile enlarged at the top, blown with hot-blast and furnished with six tuyeres arranged in a helix about its periphery, so that the currents of air are thrown into the column of material formed by the charge, at different heights, * * * the descent of the rapid succession of charges is accelerated by the great increase of heat, which also gives a very liquid iron."

This division of the zone of fusion through a certain height did not give the best results, either in regularity of descent of the charge, or in the matter of loss of iron, which he admitted was considerable.

Cupola of Greiner & Erpf.—A new system, having the merits which we have so long advocated, and which is based entirely upon the theoretical considerations herein before explained, was patented by MM. Greiner & Erpf, of Chisnyoviz (*Chisnovoda*), in Hungary, and the cupola was shown by a model at the National Hungarian Exposition at Budapest in 1885.

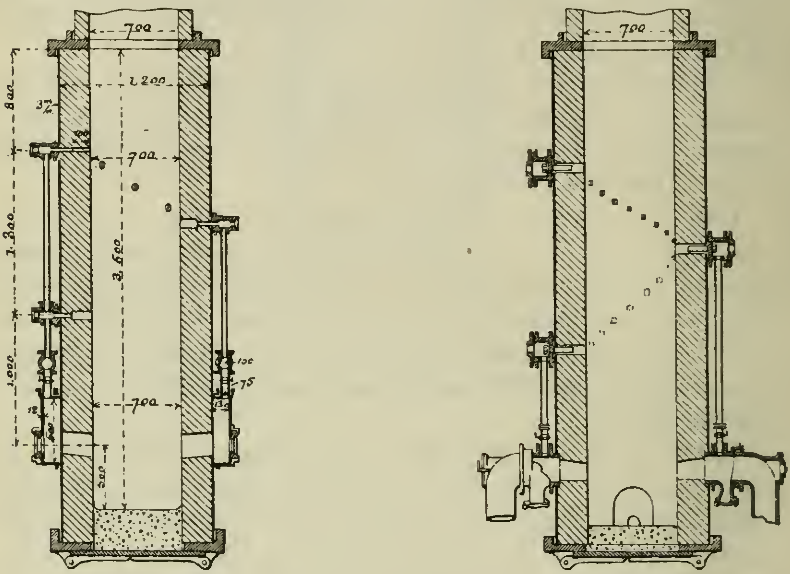
These inventors distribute, at a height (determined by experiment) above the lower tuyeres of fifty-one to fifty-nine inches, and arranged in a helical curve, the small tuyeres which furnish the air necessary for the combustion of the carbonic oxide which escapes from the lower part of the cupola; this gas burns throughout the whole of this zone with a blue flame, and the heat disengaged, which is insufficient to raise the coke to a red heat, is entirely utilized in heating the descending charge.

In the first cupolas erected on this plan, we find the small tuyeres supplied from a wind-box of cast or sheet-iron made in a helical form, which received its air from the same wind-box which supplied the lower tuyeres, or the wind-box received it by means of two vertical tubes furnished with valves (*Fig. 30*). It was therefore not possible to regulate the blast for such of these small tuyeres, or to close any of

* Bruno Kerl: *Handbuch der Metallurgischen Hüttenkunde*, *1855*; and *Berg und Hüttenkunde* for the same year.

them according to the rate of melting of the furnace, which would have been a rational method of procedure; and, moreover, the construction of this helical box was complicated and costly.

In the new arrangement finally adopted for all the cupolas of this system recently constructed, the helical box is replaced by a certain number of vertical tubes connected



FIGS. 30, 31. The Greiner & Erpf Cupolas for the complete Combustion of the Carbonic Oxide.

with the wind-box of the lower tuyeres, each being provided with a regulating valve (*Figs. 31* and *32*).

We are practically successful with this construction, in conveniently regulating the pressure and volume of the air delivered by the small tuyeres, so that the gas at the throat of the cupola is barely lukewarm and contains but a minimum quantity, and even sometimes no CO.

In the cupola tried at Chisnyoviz there was but three pounds of coke consumed for the melting of 100 pounds of iron, and the lighting coke for each "heat" was from 386 to 440 pounds.

The pressure of the blast at the lower tuyeres was from

0·70 to 0·98 inches of mercury (9·64 to 13·38 inches of water), which it was not necessary to augment, the number of orifices for the introduction of air permitting a rapid increase of the production for a small additional pressure. At the small tuyeres the pressure is reduced to 7·87 or 6·29 inches of water.

A circumstance of importance, which it is proper to present here, and which is especially characteristic of the Greiner & Erpf system, is this: When the coke used for lighting (the "bed") is being consumed, and the quantity

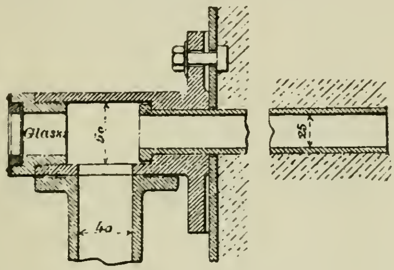


FIG. 32. Detail of one of the small Tuyeres.

of carbonic oxide passing through the neutral zone in front of the small tuyeres is still considerable, it is possible, as has been proved by various experiments, to reduce the weight of coke in the regular charges in a proportion corresponding to the heat developed by the combustion of this carbonic oxide; it is well that we can thus easily explain the apparent anomaly that in this cupola we are able to reduce the consumption of coke for melting to nearly three per cent., whereas, according to theory, it should be in the vicinity of four per cent. This is a rational utilization of the coke used for lighting, the advantage of which is more clearly manifest when but small quantities of iron are melted. We will add, finally, that the Greiner & Erpf system can be easily applied to any existing cupola at an expense of 150 to 200 francs at most.

In the following table will be found a comparison of the results obtained in various establishments which have adopted the system of Greiner & Erpf;

	Chisnyoviz Cupola.*		Westphalia Union Society.		Greiner & Erpf † Société de Construction à Prague	Greiner & Erpf.‡ Fonderie de Schlick Budapest.
	Old System. Two Tuyeres.	The Same Changed to Greiner & Erpf.	Common Ireland Cupola.	The Same Changed to Greiner & Erpf.		
Date of Experiments.	1883.	1883.	1886.	1886.	1885.	1885.
			Mean of 3 months.	*Mean of 7 heats.*		
Total number of charges, ...	207	136	. . .	. . .	414	213
Weight of iron per charge, ...	882 to 1102 lbs	882 to 1102 lbs	. . .	. .	882 lbs.	882 lbs.
Weight of coke per charge, ...	74 to 119 lbs	22 to 33 lbs	. . .	. . .	35 lbs.	35 lbs.
Total iron charged, .	213,347 lbs.	126,950 lbs.	666,489 lbs.	209,820 lbs.	363,680 lbs.	187,781 lbs.
Total coke charged, .	20,180 lbs.	3,555 lbs.	64,346 lbs.	11,053 lbs.	14,449 lbs.	7,288 lbs.
Coke for melting in per cent. of iron, ...	9·46 Per Ct.	2·80 Per Ct.	9·65 Per Ct.	5·26 Per Ct.	3·95 Per Ct.	3·88 Per Ct.
Total coke ("bed" included) in per cent. of iron, ...	12·28 Per Ct.	6·27 Per Ct	15·71 Per Ct.	9·18 Per Ct.	5 97 Per Ct.	6·68 Per Ct.

*The cupola with which these experiments were made is represented by *Fig. 30*.

†The dimensions of the cupola of the Société de Construction de Machines à Prague were Diameter, 31·49 inches; two rows of tuyeres, whose distance from the bottom of the crucible was 21·26 and 25·59 inches respectively.

‡The cupola of the Fonderie Schlick de Budapest, had a diameter of 33·46 inches, and a single row of tuyeres 30·7 inches above the bottom of the crucible.

The following corresponding particulars are also given:

(1) Société Anonyme des Hauts Fourneaux et Fonderies de la Louviere (Belgique): Changed two Voisin cupolas of thirty-one and one-half inches in diameter to the Greiner & Erpf system, and realized thereby an economy of thirty-five per cent. in coke.

(2) Ateliers de Construction du Comte Stolberg (Magdeburg): Have one cupola 19·68 inches and another of twenty-seven and one-half inches in diameter, which are run with a consumption of but 3·2 per cent. of coke for melting (not counting the "bed"); at first they reduced this to 3·0 per cent., but the cupolas "chilled" very quickly.

(3) Ateliers d'Andritz de la Société Alpine Autrichienne:

Have a cupola thirty-one and one-half inches in diameter, which consumed 5·01 per cent. of Westphalian coke.

(4) The experiments very recently made at the Cockerill establishment, at Seraing, show an economy of coke, arising from the substitution of the Greiner & Erpf system in place of the ordinary method, for the cupolas of their Bessemer steel works, of twenty-five per cent.; these cupolas perform perfectly with a pressure of 7·66 inches of water.

We will add finally that the system of Greiner & Erpf is being erected in various important works, among which we will mention: Le Creusot, the establishments of MM. Ferry et Curricque à Micheville (Meurthe-et-Moselle), etc.

We see that the economies realized by arranging the tuyeres in a helical line are very important, and that the system we are studying is the one which up to the present time gives the best practical results—embodying a simple, judicious and timely application of the most important principle relating to the working of cupolas—that of the *total combustion* of the carbonic oxide.

Notwithstanding all our endeavors, we have not been able to obtain an analysis of the gas from the throat of this cupola, and this circumstance is to be regretted, as such an analysis would theoretically confirm the advantages of this apparatus, which have already [been established in practice.

VII.

CUPOLAS FIRED WITH GAS.

In all the cupolas before described the fuel is in direct contact with the metal being melted, and it is always necessary to avoid the use of a coke containing impurities, especially when the iron is intended for the manufacture of steel.

In searching therefore for a means of separating the fuel from the metal, we find no agent superior to gas, which is the final condition of all fuel whatsoever.

The Dufréné Cupola.—The cupola of H. Dufréné (Paris,

1881) was furnished with a gas-producer, situated in front of the apparatus (*Figs. 33* and *34*); the pig-iron and scrap were

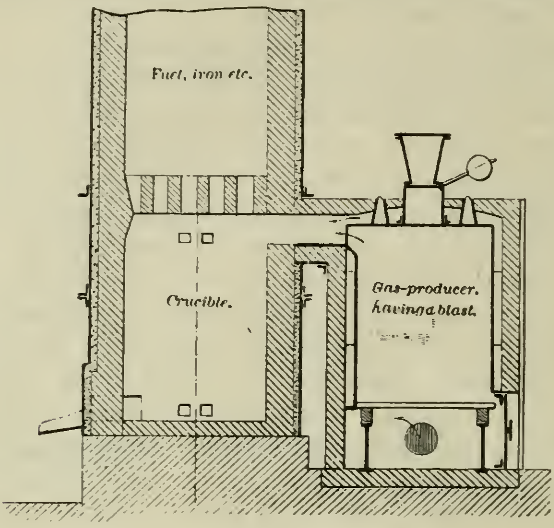


FIG. 33. The Dufréné System.

placed above the crucible upon a gridiron made of a good quality of refractory material, and the gas (previously mixed

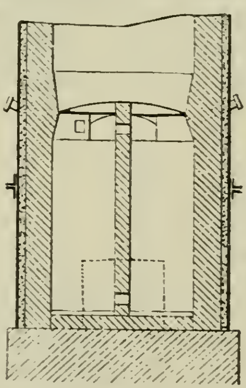


FIG. 34. Section through the Cupola.

with air, heated by circulating around the walls of the gas-producer), traverses the gridiron and the iron piled upon it.

The Besson Cupola.—M. F. Besson, of Lyons, patented, in 1881, a gas cupola for rapid melting, furnished with a kind of blow-pipe (*Fig. 35*), which developed a very great heat in

the apparatus; and there was besides above the crucible a special tuyere intended for the refining of the iron.

The Bramhall System.—In 1884, M. C. Bramhall, of Sheffield, proposed a form of gas cupola, having a regenerator with four chambers, of the kind only used in the Siemens furnace, which were traversed right and left by the gas from the throat of the cupola; the system supposed also that

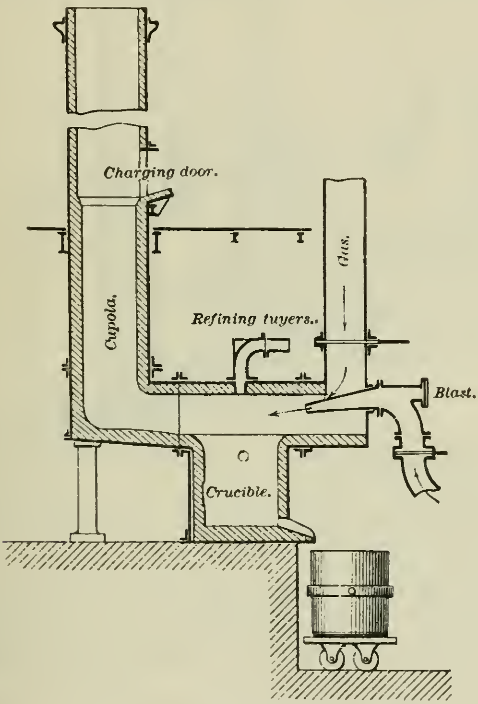


FIG. 35. The Besson Cupola.

this gas is at a comparatively high temperature, which would evidently be the result of bad management of the cupola. In all these cupolas it is necessary to watch carefully and maintain a reducing flame when we wish to obtain gray iron, but when we melt iron for puddling, it is easy to refine it by means of an oxidizing flame, but we are subject in this case to considerable loss.

The Krigar Cupola, with two Shafts.—A special system, patented by M. Krigar, of Hanover, already hereinbefore

mentioned, may be also regarded as working with gas, with this very important difference, that the melted iron comes in contact with the ashes of the coke at the lower part of the apparatus, before it enters the crucible in its front.

This cupola is composed of two distinct shafts (*Fig. 36*); the one closed at its top is intended to receive the fuel and

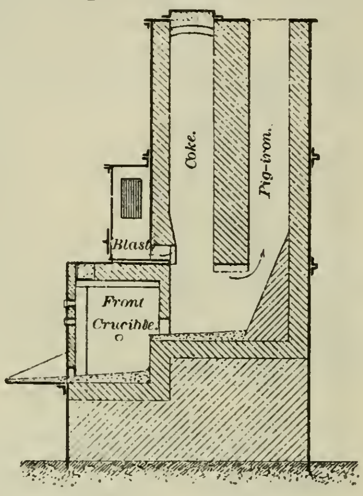


FIG. 36. The Krigar Cupola, having two Shafts.

serve as the gas-producer of the apparatus; the other receives simply the pig-iron, and materials mixed with it, such as scrap and flux.

The blast, under pressure, enters the gas-producer shaft above the front crucible, and after traversing the lower part of the fuel rises through the second shaft containing the iron.

We have given a very imperfect account of the advantages which are offered by this arrangement.

The Riley System.—The most interesting and most practical application of gas for melting in a cupola, is that made by M. Riley, of the Blochairn Works, at Glasgow,* for the manufacture of open-hearth steel; under this system the duration of the operation in the reverberatory furnace is reduced, by introducing the iron in a liquid state.

M. Riley arranges in convenient relation to the open-

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* Autumn Meeting British Iron and Steel Institute, 1885.

hearth furnace, a cupola fired by gas generated in a gas-producer furnished with a blast; in this cupola is charged the pig-iron, and then the steel scrap, without any solid fuel (*Fig. 37*).

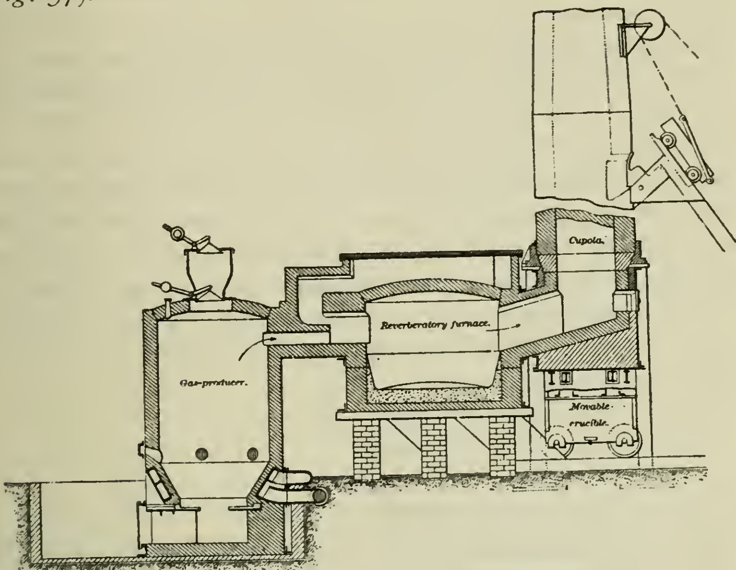

FIG. 37. The Riley Cupola and Open-Hearth Furnace.

The production of an open-hearth furnace is thus augmented in the vicinity of ten per cent.; the principle advantage of this arrangement consisting in the fact that the oxidation of the carbon and silicon takes place in the cupola, and the operation in the open-hearth is, therefore, very much more rapid.

M. Siemens * mentions some experiments of similar kind tried at Landore, by M. Hackney, these experiments, it appears, were not successful, because they charged coke also in the cupola, the result being that the decarburization could not take place there instead of in the reverberatory furnace, in which the action of the oxidizing flame upon the bath of metal covered with slag is too slow.

With the apparatus at Blochairn, the melted iron is run into the reverberatory furnace two hours after turning on

* Autumn Meeting British Iron and Steel Institute, 1885.

the gas; at first the charge of the cupola was pig-iron alone, then ten per cent. of steel scrap was added, and the addition was continued until it amounted to ten tons for each ton of pig-iron; but in this case the lining of the furnace did not resist corrosion well.*

The consumption of fuel in the gas producer appears to have been reduced to 7·2 per cent. of the pig-iron charged in the cupola; and the product per hour was two tons.

We must note that as early as 1844 Joshua Marshal Heath had taken a patent for a reverberatory furnace combined with an ordinary cupola for the manufacture of iron and steel, by the addition of manganese †—the apparatus was furnished with a carbonic oxide blow-pipe and tuyeres; —but Heath charged coke in the cupola; which resulted in the same inconvenience as in the experiment of Mr. Hackney.

VIII.

CHANGE OF THE COMPOSITION OF THE IRON IN THE CUPOLA.

In the preceding pages we have simply studied the cupola as an apparatus for the transformation of solid into liquid iron by means of fuel, either coke or gas, without fixing our attention especially upon the chemical composition of the iron and its mixtures.

The percentage of foreign matter in the pig-iron which is to be remelted in a cupola being, however, a very important factor—either when we intend to make castings or more especially when the iron is intended for the manufacture of open hearth or Bessemer steel—it has been taken account of for certain purposes. In case of castings the percentage of carbon plays a less important part than that

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* The employment of liquid iron in reverberatory furnaces has often been tried, especially for puddling, but it has always failed, in consequence of the rapid wear of the bottom of the furnace. Recently, again (1885), the Dujardin system has been patented in Belgium, and this puddling furnace appears to have worked without difficulty and economically.

† Mentioned by M. H. Bessemer at the Autumn Meeting of the British Iron and Steel Institute, 1885.

of phosphorus and sulphur. We know that a certain proportion of phosphorus is necessary to ensure the fluidity of the iron so that it will reproduce the form of the moulds with exactness; and that if it is in excess the castings, although of good shape, will be weak. A small quantity of sulphur, not exceeding 0·06 per cent. does not cause inconvenience, but if this proportion is exceeded, we are liable to have blow-holes, the iron runs thick and the castings are bad.

In case the iron is to be used for the manufacture of steel the percentage of carbon is most important, especially for Bessemer steel, and the decarburization in the cupola, or otherwise, must be avoided, or reduced to a minimum, and sometimes the carbon may require augmentation; the same is true with regard to the percentage of silicon.

Lastly, the percentage of manganese in the spiegel melted for Bessemer steel, cannot be reduced without loss, since the manganese irons are generally purchased with reference to the percentage of manganese which they contain.

In the case of those irons which are employed for puddling, we should, on the contrary, reduce their percentage of carbon, and those cupolas having tuyeres directed downward towards the crucible, as well as those having special tuyeres for refining (Besson) are recommended, in case refined iron is used for this operation; an excess of manganese is also injurious, because it makes a cinder of very great fluidity, which reduces the yield.

The employment of iron melted in a cupola for puddling is yet very much restricted, and it is not necessary to say more of it here.

Limestone.—A means used everywhere, regardless of the form of the cupola, to prevent the too great decarbonization of the iron when it passes through the zone of fusion, and encounters a current of gas more or less oxidizing, consists in the addition to the charge of a certain proportion of limestone, from thirty-three to sixty-six pounds per charge; the proportion is regulated by the per cent. of ash in the coke, so as to make with the ash a cinder of a composition suitable to envelop the particles of iron within the zone of

fusion and prevent their oxidation, and at the same time reduce the loss.

If it is considered desirable to avoid the presence of sulphur in the iron, when the coke used contains it, we endeavor to obtain a basic cinder which absorbs the sulphur of the coke instead of allowing it to pass into the iron.

Quality of the Fuel.—The quality of the fuel charged into the cupola, therefore, plays an important part from a chemical, as well as from a physical point of view.

The sulphur contained in the ash of the coke tends to pass into the iron, and we see that that may be prevented by a basic cinder, which we make by charging a large quantity of limestone, which necessitates a large consumption of fuel, and augments the net cost.

This is also true when the coke is very ashy and of feeble tenacity, as it is then crushed in the charge, whose descent is irregular, and the coke dust produced is raised by the blast and thrown out of the chimney without having been utilized. The porosity of the coke is also a factor to be considered, inasmuch as coke which is very dense produces more carbonic acid than a porous coke, which presents a large surface of contact for the air.

Oxygen in Excess.—The presence of oxygen in excess in the gas has a very unfavorable influence, because the decarburization of the iron is very great and at the same time its waste is increased, but, however, when the zone of fusion is of small extent, this waste is diminished, for the iron is exposed for a less time to the action of the gas; which appears to be the case, for example, in the Herbertz cupola.

Percentage of Manganese.—With regard to the percentage of manganese in the iron, and especially in spiegel, it is very much reduced in the cupola, as a great part of the manganese passes into the slag, especially when the temperature is low; then, again, considerable manganese is lost in case the cinder is acid, and the temperature too high, accompanied with a low pressure of blast.

The analysis published by M. de Köppen* relative to

* *Dingler's Polyt. Journal*, 1879. Vol. 232, p. 53.

the fusion of spiegel in a cupola, indicate an increase of Si, C, Ph, and S, and a decrease of Mn.

The augmentation of the former substances results in reality from a waste of iron during melting, which was very great, and, as regards the carbon, probably there was a heavy charge of coke with ordinary iron.

The proportions in which the three most important substances varied in five different experiments are given by M. de Köppen as follows:

Amount of	I		II		III		IV		V	
	Before.	After.	Before	After.	Before.	After.	Before.	After.	Before.	After.
	Melting in the Cupola.									
Si, per cent., ...	0·14	0·50	0·12	0·49	0·12	0·42	0·40	0·66	0·33	0·41
Mn, per cent., ...	14·81	8·96	14·25	10·52	14·98	11·06	16·24	10·98	14·93	12·03
C, per cent., ...	3·98	4·13	4·40	4·62	4·48	4·60	4·62	4·96	3·43	3·67

The cinder of these meltings has an average composition of 33·63 per cent. SiO_2; 21·45 per cent. CaO; 11·73 per cent. Al_2O_3; 20·47 per cent. Mn., and 5·95 per cent. Fe.

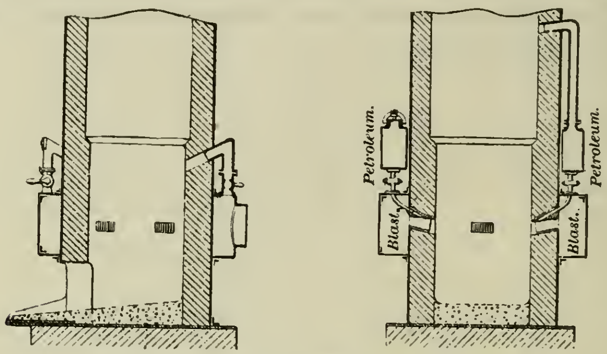
THE INJECTION OF VARIOUS MATERIALS BY THE BATTY SYSTEM.

It has been attempted to modify the composition of the iron by the introduction of a variety of materials in the cupola; Dingler* mentions a cupola invented by Batty, of New York, in which it is proposed to introduce, by the tuyeres, pulverized fuel, such as the carbon deposited on the interior of gas retorts, or the residue of the distillation of petroleum, which leave no ashes. Batty proposes thus to avoid the oxidizing action of an excess of blast, by immediately combining all the oxygen with the injected carbon, thus making a neutral or even a reducing flame; promoting the formation of a "noze" on the tuyeres, obtaining a very

* *Dingler's Polyt. Journal*, 1877. Vol. 224, p 105; *Polytechnic Review*, 1877.

high temperature and reducing the waste; which results, it seems to us, have been attained by very much more simple means.*

The Voisin-Bichon Cupola.—Another system, which has been much used in France, is the Voisin-Bichon; this consists in the injection of petroleum, or other heavy oil, by means of tubes of small diameter extending from two reser-



FIGS. 38, 39. The Voisin-Bichon Cupola.

voirs of the oil, and entering the cupola through two opposite tuyeres of the lower row; a tube of larger dimensions enters the shaft at a certain height for the purpose of heating the oil by the gas, so that it will readily flow to the lower tuyeres (*Figs. 38* and *39*).

The principal advantage of this arrangement consists in the possibility of obtaining very high temperatures, for the fusion of large masses, by the employment of these heavy oils.

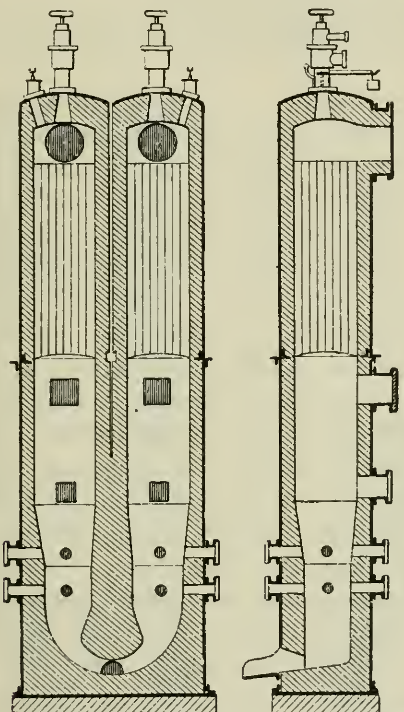
No details have been given relative to the experiments which have been made with this apparatus; these would have been interesting, especially if they showed the net cost.

In the Voisin-Bichon each of the tuyeres of the upper row is served by a special tube, by which the admission of blast can be regulated at pleasure, and we are told that by closing the upper row of tuyeres, at the beginning and end

* The injection of powdered fuel has been tried repeatedly; in blast furnaces in Bessemer converters (the Braconnier process for example), but the results have not been commensurate with the high cost of the apparatus employed.

of a "heat," the iron was brought down very hot, and that it was possible to introduce a charge of iron at the end of the heat, without any fuel.

The Herdlitschka System.—An arrangement, very scientific and practical, invented by M. Herdlitschka,* consists of two communicating cupolas, joined by their crucibles (*Figs. 40* and *41*). These cupolas are intended to work alternately, and are each furnished with a regenerator placed in the



Figs. 40, 41. The Herdlitschka System.

upper part of its shaft; the various materials intended for the purification of the iron are introduced above these regenerators by a steam injector.

After the fusion of the iron in one of these compartments, and the metal collects in the common crucible, the openings

* *Dingler's Polyt. Journal*, 1880. Vol. 4, p. 318. (Whatever else this system may be, it does not appear very "practical" to the translator. W.F.D)

of this compartment are all closed, and the proper injector is put in action, forcing the chemical reagents through the regenerator (where they are heated), and causing them under pressure to traverse the liquid iron; it is, however, necessary to previously remove, through a special door, the cinder and unconsumed coke from the compartment. M. Herdlitschka claims to thus deprive the metal of a great part of the sulphur and phosphorus, by the injection of steam, carburetted hydrogen, etc.

It is not very probable that this apparatus has been put in operation.

Manganiferous Coke.—A process, patented in 1884, by the Société des Aciéries de Longuy, consisted of the employment in a cupola of a special coke, obtained from a mixture of coal and manganese ore in an ordinary coke oven; the cinder produced is pretty basic, and the inventors say that it will remove every trace of sulphur from the iron.

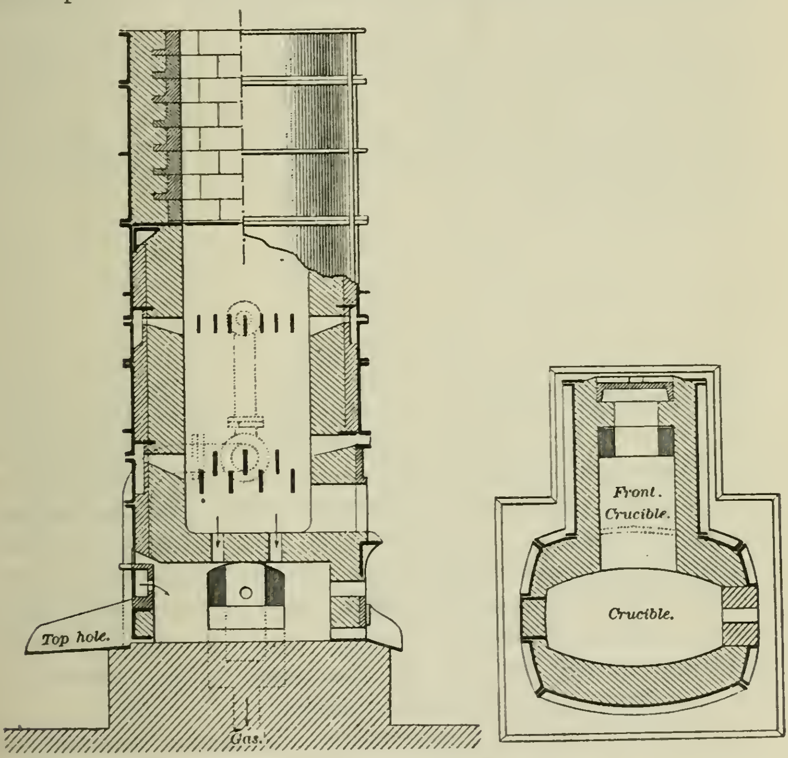
The Ibbruger Cupola.—In 1879, M. Ibbruger* built at Norden a cupola having a rectangular section, with convex sides, similar to a Rachette furnace; it was fitted with thirty-six slits (to serve as tuyeres) in two rows (*Figs. 42* and *43*). The crucible proper was separated from the zone of fusion by a wall of refractory material, and the gas was directed from above downward, as in the Krigar cupola, by aspiration, as already described, and passing over the metal in the two crucibles, thus preserving it from oxidation and maintaining its percentage of carbon nearly constant. A supplementary tuyere in connection with the crucible is intended to ensure a perfect combustion of the gas, and to allow of an oxidizing flame if necessary. The experiments, which have been made with this cupola by M. Jüngst, of Gleiwitz,† show that the same iron melted three or four times improved in quality by the graphite being slowly transformed into combined carbon. The pressure of the blast was 24·4 inches of water. The total consumption of coke was ten per cent. This cupola will melt with advantage as much as forty per

* *Dingler's Polyt. Journal*, 1880. Vol. 245, p. 14.

† *Eisen Zeitung*, 1885, p. 678.

cent. of scrap placed in the crucible or mixed with the liquid iron. The results appear to have been satisfactory.

The Krupp System.—We speak lastly of an apparatus, patented in 1878 by M. F. Krupp, intended especially for the purification of iron.* It is based upon the principle, that if we melt in a furnace having its shaft walls made of neutral bricks, and its crucible lined with basic or neutral material, the liquid iron, when mixed with basic oxide of iron, with or without oxide of manganese or lime, loses in great part its manganese, silicon, sulphur and phosphorus.



FIGS. 42, 43. The Ibbruger System.

The iron, mixed with ore (FeO), is melted at first in a cupola furnished with two rows of tuyeres, and which is on a higher level than the purifying cupola.

The experiments made in a small temporary apparatus

* *Dingler's Polyt. Journal,* 1880. Vol. 235, p. 373.

have given results sufficiently remarkable to justify us in reproducing them here:

Percentage of	C	Si	Mn	Cu	P
Impure iron, ...	3·730	0·470	3·560	0·250	0·600
Purified iron, first trial, ...	3·000	0·004	0·128	0·250	0·136
Purified iron, second trial, ...	3·400	0·005	0·210	0·250	0·187
Purified iron, third trial, ...	3·400	0·002	0·470	0·250	0·210

The ore employed for purification contained 98·20 per cent. oxide of iron, 0·54 per cent. phosphoric acid and 0·10 per cent. of lime; the cinder, which was the richest in phosphorus, gave on analysis: 5·28 per cent. phosphoric acid, 26·30 per cent. oxide of manganese (MnO), 41·28 per cent. oxide of iron (FeO) and 17·60 per cent. of silica; it also contained 1·46 per cent. CaO, 0·36 per cent. MgO and 0·66 per cent. of S.

IX.

CONCLUSION.

The result of this study shows that the lowest net cost of the fusion of iron in a cupola has been reached with that form of apparatus in which especial attention has been paid to the complete combustion of carbonic oxide (Voisin-Bichon, Greiner & Erpf). And that the employment of blast heated by means of the gas from the top of the cupola; the substitution, for a pressure blast, of a natural draft, or a draft created by a steam exhauster; the injection of various materials by the tuyeres or otherwise, do not appear to have resulted in any decided economy.

We think that the improvements in cupola practice for which it is still profitable to search, relate to the modification of the composition of the iron, by the removal of its impurities, with a view to its final employment for the manufacture of steel or for puddling.

These results can be attained by the addition of various materials, either to the charge or in the crucible; or else by

the employment of a special lining for the walls of the cupola; which, last, would not be applicable to ordinary cupolas intended merely for melting iron; but more properly to such improved siderurgical apparatus intended as a substitute for the expensive and complicated methods of dephosphorization in a converter or basic open hearth, on which metallurgists have in recent years concentrated all their efforts. It is true that it would be more direct, if we could obtain the same results in the blast-furnace; but the numerous researches made in this direction have been unsuccessful, for the reason that such furnaces are too large, the choice of materials generally restricted, and the difficulty of regulating the operations of a blast-furnace in case the composition of the charge is very complicated. In the actual state of things, therefore, we must record the best results obtained up to the present time in the remelting of pig-iron, for which we are indebted to the simple and judicious application, by MM. Greiner & Erpf, of the principles previously used in the Voisin cupola, and the cupola at Angiers, etc., and afterwards employed with some improvements by M. Bichon, which, in spite of their manifest advantages as compared with other apparatus, have not received from engineers of steel works and foundries the attention which they merit.

The accompanying table gives the relative dimensions, the product and the consumption of fuel of thirty-three cupolas of various construction, and enables us readily to compare the advantages in economy of fuel of the different systems that have been actually much employed.

THE NICARAGUA CANAL.

By COMMANDER H. C. TAYLOR, U. S. Navy.

[*A paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *Wednesday, October 15, 1888.*]

JOS. M. WILSON, President, in the Chair.

Commander TAYLOR spoke as follows:

MR. PRESIDENT, AND MEMBERS OF THE INSTITUTE:

It appears that, after all, Columbus was not mistaken in sailing westward from Spain in search of a convenient route to the East Indies.

The intervening continent, which checked his progress and disappointed his successors in American exploration, made his avowed attempts to reach the Indies a complete failure, though the memory of this failure was lost and obscured in presence of the glory of a greater success, the undreamed glory of a new world.

It is a pleasing thought, that four centuries later, perhaps in the very year 1892, we shall see the wisdom of that valiant spirit justified, and European fleets sailing westward from Spain through an isthmian ship-canal, as the most convenient route to the far East. The mind dwells with satisfaction upon this justification of the great navigator, and sees, with a singular pleasure, ships coming out of Cadiz, dropping almost immediately into the soft current of the northeast trade-winds, and blown by them smoothly across the Atlantic and Caribbean, between the islands of the West Indies, and quite into the entrance of a Central American ship-canal; issuing thence into the same belt of gentle favoring winds, and carried by them across the broad Pacific to those rich coasts and islands of the far East which were ever such powerful magnets to the earlier navigators. Nor is this pleasing thought any longer an unreasonable one. That ships shall cross the isthmus from sea to sea has been decided. The clamor of commerce and its shipping can no longer be disregarded.

Transit across the narrow lands of Central America is certainly to be provided, and the only questions are when, where and how.

The search for a practicable canal route succeeded to the long persistent examination which had caused explorers for so many years to penetrate every inlet from Newfoundland to La Plata, in the hope of finding the strait which they confidently believed nature had provided as a means of communication between the oceans.

"Men," said Humboldt, "could not accustom themselves to the idea that the continent extended uninterruptedly from such high northern to such high southern latitudes." From the year (1513) when Nuñez de Balboa first looked upon the wide sweep of the Pacific, a century was occupied in fruitless efforts of gallant and capable men to discover that strait which nature should have placed there—but did not.

The Cabots worked in the north. D'Avila, under secret orders of the Spanish king, scrutinized eagerly the isthmuses and the Spanish Main; while De Solis, under similar instructions, explored the coast of Brazil, and while hopefully ascending the great estuary of La Plata, was killed by the natives of that region. Ponce de Leon sailed hundreds of miles northward from Panama on the same errand; Cabrillo and other lieutenants of Cortez groped north and west from Tehuantepec, as far as the vicinity of the present Monterey and San Francisco; and Cortez himself, under the urging of his royal master, King Charles V, of Spain, struggled against much obstacle and disaster to achieve the desired discovery. When, however, the Gulf of California was found to have a head at the mouth of a great continental river, the intelligent Spanish explorers, already doubtful, could no longer believe in the existence of any communication between the seas, and the "secret of the strait" faded away into the dreamland of legend and fable. Other nations than Spain still hoped. As late as 1607, we are told by Bancroft, Virginia colonists were ordered to seek communication with the South Sea "by ascending some stream which flowed from the northwest," and that it was

in ascending the Chickahominy with this end in view that Captain John Smith was captured by the natives; and thus another touch of interest is added to the adventurous record of this man of ordinary name and extraordinary life.

The strait was indeed an idea difficult to surrender. It *ought* to be true, they said. The seas are so close together for 1,000 miles. Commerce between "Cadiz and Cathay" so greatly needs it. It *must* be so. That it should not be was, in the words of the writers of that day, "repugnant to the interest of humanity." The "secret of the strait" *must* be disclosed.

The world moving, like all large bodies, slowly toward conviction, did become at last convinced that nature had not pierced the barrier for our use and comfort, and this conviction once forced upon it, plans for an artificial channel began soon to be suggested. The idea had been touched upon by Balboa, Cortez and Saavedra, but the first record we have of a practical suggestion is that of the Spaniard Gomara, who urged the idea upon Philip II in 1551, but the son was not the father; nor were such leaders as Cortez to be found, even had the spirit of Charles V still animated the actions of the Spanish throne.

From this time forward, the Spanish government seemed disposed rather to smother than to encourage any efforts to connect the oceans. As the old-time Spanish vigor departed, the feeling grew that if any good route were found, it would only be snatched from them by some of those daring Drakes and Grenvilles, who, roaming the seas at the head of brave and reckless companions, sought every opportunity to insult Spain and plunder its colonies.

A long period now passed, during which no interest was evinced in the canal question. The mystery with which the Spanish government had wished to cover it was complete. If the desire for knowledge came later, the failing vigor of that nation stood in the way of any successful investigation.

It was left for Humboldt to reawaken an interest among the nations, and to indicate localities where favorable results would be most likely to be met with by the explorer

and surveyor. In his opinion, the valley of the Atrato and the Isthmus of Darien were points where examinations should first be made. Later we shall see how thoroughly these localities have been surveyed, and with how little success.

Before Humboldt's time Admiral Horatio Nelson had become thoroughly interested in the San Juan River and Lake Nicaragua, as being the great route for future transit between the oceans, and one of his few reverses was sustained in attempting to gain a foothold in Nicaragua for the British navy, being defeated and driven back while attempting a hostile advance or reconnaissance up the San Juan.

In 1825 Nicaragua invited the co-operation of the United States in the construction of a canal by way of Lake Nicaragua and the River San Juan, but with no satisfactory results. In the same year Mexico caused a rough survey to be made of the line *via* the Coatzacoalcos River and the Isthmus of Tehuantepec, resulting in an official report that the "canalization of this isthmus was problematical and gigantic."

Later, in 1828–29, a survey was made under orders from General Bolivar of a route substantially the same as that of the present railway between Aspinwall and Panama. Nothing was effected by this action, except to put an end to the popular error that the mean levels of the oceans on opposite sides of the isthmus differed appreciably. There are still some, I believe, among those who have not given their attention to this subject, who are yet ignorant that differences are caused only by tides, winds, barometric pressures, and other temporary disturbing causes, and that the levels of the two seas may be regarded as practically the same.

Many other attempts were made in the ensuing years, and with uniform lack of success. In 1830, the Netherlands, beginning fairly enough, were obliged by the revolution in Belgium and its separation from Holland to give up the project. In 1835, President Jackson appointed Mr. Charles Biddle as special agent to promote the idea of an isthmus canal, and to visit the Central American countries for that

purpose. Mr. Biddle met with many difficulties, and returned to the United States with nothing accomplished of value, and from this time the projects became too numerous to be even touched upon in a paper of this scope. M. Guizot, under Louis Philippe, urges interoceanic canal questions upon the attention of the Chamber of Deputies. A bishop of San Salvador goes to Rome and urges the importance of a canal upon the Pope. All of no avail; but in 1849, a success is scored, not for a canal, but for the Panama Railway.

This method of transit, of vast service to commerce, has, however, by providing an imperfect system, retarded the realization of that dream, long cherished, of a water connection between the oceans.

We must not omit, in this brief sketch, to record the attention which Louis Napoleon gave to the project. He studied it carefully, and had at one time thoroughly prepared himself to assume the presidency of the "Canal Napoleon de Nicaragua." His views are best set forth by quoting from his own writing in the magazines of that day, before he became Emperor of the French.

"The geographical position of Constantinople is such as rendered her the queen of the ancient world. Occupying as she does the central point between Europe, Asia and Africa, she would become the *entrepôt* of the commerce of all these countries, and obtain over them an immense preponderance; for in politics, as in strategy, a central position always commands the circumference. There exists in the new world a state as admirably situated as Constantinople. We allude to the state of Nicaragua. As Constantinople is the centre of the ancient world, so is the town of Leon the centre of the new, and if the tongue of land which separates its two lakes from the Pacific Ocean were cut through, she would command, by virtue of her central position, the entire coast of North and South America.

"The State of Nicaragua can become, better than Constantinople, the necessary route of the great commerce of the world, and is destined to attain an *extraordinary degree of prosperity and grandeur.*"

Here, at Brito, instead of Leon, will rapidly be created one of the great world centres of industry, an *entrepôt* of vast international commerce, a focus of interchange for the products of the globe.

We must now, having glanced briefly at the past history of this great problem, make a rapid review of the work of to-day, and consider the various routes which have been examined during the last few years. Although the boiling-down process of precise instrumental surveys has reduced these possible lines of transit to three, Panama, Nicaragua and Tehuantepec, and although the further process of actual digging and building will, it is believed, soon rule out Panama and Tehuantepec, leaving only Nicaragua, yet many other routes, methods and plans have been examined, and no portion of the isthmuses can be said to have been neglected.

Beginning at the south, we find the Atrato River, recommended by the great Humboldt, rising in the mountains of Western Colombia, and pursuing a northerly course to its mouth in the southwestern corner of the Caribbean. Although its waters empty into the Eastern Sea, its course is parallel to the Pacific Coast, and only about fifty miles from that ocean. The main stem of the Andes, whose eastern slopes it drains, separates it throughout its course from the Pacific. This range is throughout this portion not of great elevation, and numerous tributaries afford, in their valleys, easy grades from the Atrato to or toward the crest of the divide.

Humboldt was told of vessels passing from the head waters of the Atrato to those of a small stream flowing southwest into the Pacific, by means of a short canal. Later examinations show that the vessels were canoes, the canal, if not mythical, was a ditch, and that a long and high portage intervened over which the canoes were dragged. Lower down the Atrato several lines of levels were run across the divide, with much care and labor, following the lines of some of the principal tributary streams entering from the westward. In these it was found necessary that

the summit levels should include tunnels many miles in extent, high enough to accommodate ships with at least the lower masts left standing, and involving enormous expense. Attempts were also made to connect the Gulf of San Miguel with Caledonia Bay on the Caribbean side; and at a point farther west, to connect the Gulf of San Blas on the Caribbean with the Bayano River, emptying into the head of Panama Bay. Here again long tunnels or other formidable obstacles were soon revealed as the lines of levels were carried across.

Next came the line of the Panama Railroad, and here high hopes were entertained, for a railroad was already there, and the Chagres, a large stream, debouching near Aspinwall, has its source well over toward the Panama or Pacific side of the isthmus. After careful surveys on this line, it was decided that a lock canal was possible, though difficult, costing over $100,000,000, and meeting with trouble in supplying water for its summit level. A canal at the level of the sea was deemed impracticable, it being considered that the violence of the freshets in the Chagres placed it beyond successful engineering control.

The surveys of these routes had been carried on by our Government, but the interest felt to-day in the Panama Canal project makes it proper for me to notice other work in that locality, for French enterprise had begun to stir, and a speculative company, known as the "International Society of the Interoceanic Canal," had been formed in Paris in 1876.

I will not fatigue the INSTITUTE with the monotonous details of continuous blunders. It is the wonder of modern civilization that Count De Lesseps should have been able to raise $420,000,000 to perform a work which was known to the world, outside of France, as impracticable if not impossible. Briefly, we will say that certain French gentlemen obtained from the United States of Colombia a concession, and having interested M. De Lesseps in the project, persuaded him to assume the leadership of the Panama sea-level canal. De Lesseps, in 1879, caused the French Geographical Society to assemble, by invitation, an International Canal Congress. This Congress, thoroughly under

his influence as to its committees, and largely so as to the body of the Congress, decided, against the earnest protest of the ablest engineers in the world, to approve the sea-level plan at Panama. The development of the project since that time can be read in the newspapers of the day. The company owes about $420,000,000, with an interest and fixed charges of about $22,000,000 per year. I do not understand that M. De Lesseps claims that more than one-fifth of his work is completed, and my own studies of the subject, coupled with personal observations in the earlier part of the work, convince me that one-tenth is nearer the actual amount accomplished. Lately a change has been made in the plan, and a temporary or provisional lock canal is proposed, and work is now going forward on that basis.

A glance at the comparative profile of Panama and the comments of *Engineering News*, of June 2, 1888, thereupon, to be found in the Appendix, will show that, although much less remains to be excavated under the lock plan than under the sea-level plan, nevertheless it bears such a proportion to the effective cube already excavated, that we may safely say that only thirty per cent. is done toward a lock canal.

In all these estimates we leave to one side the question of the control of the Chagres River, a problem which seems hopeless to many of the best engineers.

These facts do not surprise those who have studied the question. Great engineers warned Paris and the world of just such a disaster at the Paris Congress, while they urged Nicaragua upon their attention as being an entirely feasible, economical engineering project. We know why they were not listened to; we know how the French clustered loyally about their famous De Lesseps; how he, totally ignorant of the topographic and climatic difficulties, flushed with success and impatient of contradiction, would hearken to nothing but a French plan, executed by Frenchmen.

We cannot doubt the brilliancy of De Lesseps' vigorous intellect. His long career vouches for it. But Napoleon was brilliant, and yet committed the foolishness of invading Russia. He was great, but he had his Waterloo. De Lesseps is great, but he has his Panama.

Omitting Nicaragua, for the present, and referring briefly to the lines in Costa Rica and Honduras, the former connecting Chiriqui Lagoon with the Gulf of Dulce, and the latter crossing from the Bay of Honduras to the Bay of Fonseca, they may be summed up by stating that excellent locations for railways were found here, with good harbors at the termini, but that the elevation of the mountain ranges in the vicinities made canals impossible.

Passing on still farther to the north and west, we come to the northernmost of the isthmuses, that of Tehuantepec. Cortez satisfied himself with regard to its usefulness as a land transit, and sent by that line much of the equipment arriving from Europe for his Pacific fleets fitting out for exploration and conquest. Later on, when no longer used, the world fell again into ignorance concerning it, and the ancient legends of a strait existing here gained a fresh credence until as late as the middle of the last century.

The late Captain Eads proposed, as a canal here was impossible, to take sea-going ships, loaded with heavy cargoes, out of the water, lift them upon a cradle, and carry them by rail across six hundred and fifty feet of elevation, through swamps and across streams, and finally to lower them into the water on the other side of the isthmus.

The mass of engineering opinion regards the building of embankments, the management of grades and turnings, to be, under this heavy load, difficult and perhaps impossible. The mass of nautical opinion considers the lifting and carrying of heavy ships, loaded with railroad iron or other heavy weights, to be dangerous in the highest degree to the integrity and safety of the ships' hulls.

There is more than one way of avoiding breaking bulk easier and simpler than this. Ships for this isthmus trade can be fitted with interior decks on which rails are laid for cars of the lightest and snuggest construction, stowing closely together, and losing but little stowage room by their interstitial spaces. Cargo may be stowed in them, and these cars, of a size to fit a narrow-gauge road across the isthmus, can be hauled out through the bow or stern ports, in a dock arranged to float the ship higher or lower, as

needed, in order to bring its decks in succession at the level of the shore tracks.

Those cars would be run across a cheaply constructed narrow-gauge railway, and run into the hold of a ship on the other side of the isthmus, fitted in the same way to receive them.

Some little stowage space would, of course, be lost, but this loss would be slight compared with the enormous tolls each vessel would have to pay to allow dividends on the expensive railway needed to carry bodily a large vessel and her cargo.

This is not a specially good project; but it is one of many plans which are more feasible, economical and sensible than the project of a ship railway.

It is a pleasure, after describing these problematical locations, these mistakes, these costly blunders, to have the privilege of describing briefly to this distinguished gathering the project of a Nicaragua Canal. The value of this route has been long known. Here, in Nicaragua, the backbone of the continents and isthmus, running parallel and close to the Pacific shore, sinks to its lowest point, while its eastern slope is washed by that great sheet of inland sea, known as Lake Nicaragua. At this low point the divide is less than fifty feet above the level of the lake, and about one hundred and fifty feet above the mean level of the Pacific. Though the western shore of the lake is but fifteen miles from the beach of the Pacific, the lake drains through the River San Juan, into the Caribbean Sea. The lake is deep and unobstructed, and the river, already navigable for light-draught steamers throughout most of its length, requires but a little labor to deepen it.

Here, with such a vast water supply at the summit, with the lake itself as *a summit level*, nature seems indeed to have offered assistance in connecting the oceans. No great engineering difficulties in utilizing the lake are claimed, even by opponents of this route. There are no startling propositions connected with the plan.

Nature has decided its location, and it only remains for man to stake it out.

The lake and San Juan River *must* be the great part of the canal, no matter how the openings to the sea are made.

The route extends from Greytown on the Atlantic to Brito on the Pacific, a distance of 169·67 miles, divided as follows:

	Free Navigation.	*Canal in Excavation.*
Greytown to Deseado Basin, ...		12·37
Deseado Basin, ...	4·00	
From Deseado Basin to San Francisco Basin, ...		3·07
San Francisco and Machado Basins, . . .	11·00	1·73
River San Juan, ...	64·00	
Lake Nicaragua, ...	56·50	
From Lake Nicaragua to Tola Basin, . . .		8·22
Tola Basin, ...	5·28	
From Tola Basin to Brito, ...		3·50
	140·78	28·89

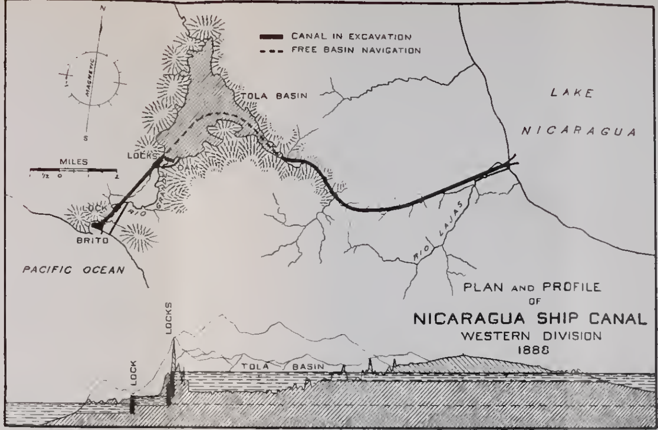
The Deseado and Tola basins are new features, brought out by the last location, as well as an increase of 2·13 miles in the length of free navigation in the San Francisco and Machado basins, or in other words, the last location has reduced the length of canal in excavation by that same distance, while the summit level has been extended from 144·8 miles to 153·8 miles.

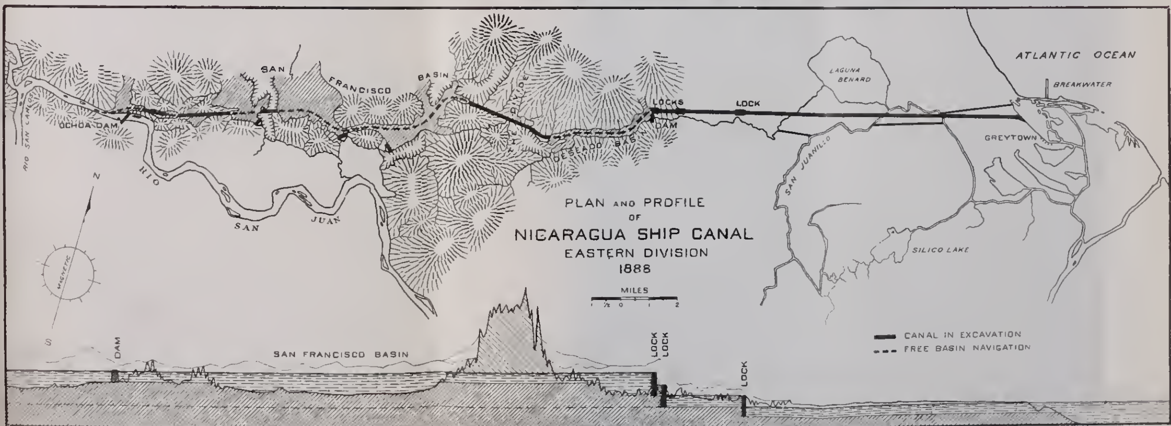
It will require some time to complete the estimate of cost on the new location, but it may be safely stated that at least ten per cent. will be gained on the total cost based on the survey of 1885, which is $64,036,197, including twenty-five per cent. for contingencies.

The accompanying plans and profiles (*Plates I, II*) explain themselves:

The principal dimensions of the canal in excavation are as follows:

Material.	Width.		Depth.
	Bottom.	Top.	
Rock, ...	80	80	30
Earth, ...	120	180	30
Sand and loose material, ...	120	360	30





D. A. PARTRIDGE PHOTO-LITH, 35 N. TENTH ST. PHILA

The minimum radius of curvature is 2,500.

The leading engineering features, in greater detail, are: The construction of two harbors at the termini of the canal, Greytown on the Caribbean Sea, and Brito on the Pacific Ocean; the damming of the waters of the San Juan River, for the purpose of raising and maintaining the level of Lake Nicaragua and the river at about 110 feet above mean tide; the formation of artificial basins at different levels by means of dams and embankments, and the use of locks, to pass from one level to another.

The harbors are, at present, not in good condition, but by a comparatively small expenditure of money, can be made to offer protection to vessels of the largest class. The harbor of Greytown is now closed to vessels of more than six feet draft, but the facility for reconstruction is such that in three months from the commencement of work, at the outside, a temporary opening can be made, and material safely landed by vessels of fifteen feet draft. The further improvement of Greytown harbor is only a question of the continuation of the temporary opening. It is proposed to make this opening through the sand bar which now closes the once flourishing port of Greytown, by means of a temporary jetty of brush and pile, to furnish protection to a dredge working to cut through the bar. This jetty will also give the necessary protection for the maintenance of the cut so made. The extension and strengthening by stone, of the jetty, and the continuation of the dredging, to form a permanent harbor, is simply a question of time.

The construction of a wharf at Greytown, and of a railroad from it along the line of the canal, are the connecting links in the chain of supplies. The projected final depth of the harbor is thirty feet.

The harbor of Brito will be formed by two breakwaters, giving protection from the long swell of the Pacific, and the excavation of the harbor itself from the lowlands forming the banks at the mouth of the Rio Grande.

From Greytown, the sea level is carried to the site of the first lock, which is located at the eastern end of the valley of the Deseado. Here is a lift of thirty-one feet, into the

first basin, formed by damming the lower waters of the Deseado River. Through this basin we approach rapidly locks Nos. 2 and 3, which, with their respective lifts of thirty and forty-five feet, bring us to the summit level, and clear sailing through the basins of the Deseado and San Francisco, with the divide cut between, and thence into the San Juan River, across the lake and finally through the La Flor Basin. Here, by means of a double lock, with a total fall of 85 feet, and again by the sixth and last lock, we descend to the sea level. This last lock has a variable lift, depending on the state of the tide, which on the Pacific side has a mean rise and fall of about six feet at present. The mean lift of the tidal lock is twenty-five feet. The locks are 650 x 70 x 30 feet.

As before stated, one of the principal features of the canal is the formation of large basins, by means of which the greater part of the canal is made a navigable body of water, instead of a narrow cut through the earth. As now projected, the first basin begins at the site of lock No. 1. This basin is formed by an embankment 1,100 feet long and twenty feet high, which maintains the level of the water at thirty-one feet above the sea level. A second embankment 1,400 feet long and 86 feet high, near lock No. 2 (with a lift of thirty feet), maintains the level in a small basin at sixty-one feet. A third, but smaller embankment, at lock No. 3, keeps the level at 106 feet. This is the summit level already referred to as extending from lock No. 3 to lock No. 4, a distance of 152 miles. The dam across the San Juan river at Ochoa, just east of the San Carlos, is 1,500 feet long by sixty-five high. Its purpose is to bank up the waters of the San Juan River, to a level of 106 feet or fifty-eight feet higher than at this point now. By this means a lock and a large amount of dredging is saved, and the San Juan is thus made practically navigable to Castillo, while the amount of river dredging above this point is reduced to a minimum. It will be noticed that at the dam, the level is given as 106 feet. At the lake it is 110 feet, and it is proposed to give the river a fall of four feet from the lake to Ochoa, a distance of about sixty-four miles. Again, on the

Pacific side, an embankment 2,100 feet by eighty is made across the Rio Grande. This floods the valley of the upper Rio Grande and its tributary, the Tola. Then by cutting through the low continental divide to the lake, the summit level of 110 feet is maintained to within three miles of the Pacific Ocean. The surplus flowage is provided for in all cases, by numerous waste-weirs of ample capacity. Lake Nicaragua has a water shed of 8,000 square miles.

The Rio San Juan, *its only outlet*, discharges at its lowest stage, near the close of the dry season, 11,390 cubic feet per second, or 984,096,000 cubic feet per day.

The amount of water required for thirty-two double lockages is 129,479,968 cubic feet, or a little more than one-eighth of the total supply of the lake alone, to which must be added the flow of the several tributaries of the San Juan, between the lake and the sea, and the San Francisco and its tributaries.

As this supply is *from the summit*, the danger of a dry summit level, which is so serious a question with the Panama scheme, is impossible here. It is also a favorable point that the canal will be a fresh water one.

Contrary to the general opinion, the climate of Nicaragua is an equable and almost a temperate one.

No case of yellow fever has ever been known at Greytown, and Col. Squier, in his work on Nicaragua, lays stress on the fact that, while the Mexican and Central American coasts, north and south of Nicaragua, have been visited frequently by epidemics of cholera, and are subject to yellow fever more or less every year, no epidemic of any kind is known to have visited either the Pacific or Atlantic coasts of Nicaragua.

I refer to the late expedition in confirmation of this statement.

Of the forty-nine engineers and 150 men in the employ of the company, there was not a single case of serious illness, not a single case of dysentery, and but few cases of slight intermittent fever. None of these latter caused the loss of the services of those affected for more than three days.

When it is stated that the whole expedition was daily

exposed to constant wettings and dryings, often shoulders deep in marsh, and had frequently to pass the night in wet garments, the above statement would be a remarkable one for any country.

The country is capable of being developed to a great extent. It is rich in minerals, particularly gold, mines of which are now being successfully and profitably worked. Cocoa, indigo, coffee and fruit are the principal agricultural products, but the country is capable of producing a greater variety, and is particularly adapted to the growth of market garden products.

The timber is remarkable for its variety and value. Mahogany, rosewood and dye-woods are abundant, and even now large shipments of the latter are made from the Pacific Coast.

So far but one serious objection has been raised against this project, and that is that the route lies in the region of earthquakes. Upon this subject, the following extract from Mr. Menocal's report bears with much force:

"The buildings (referring to ruins left by Walker's expedition) stand to-day just as he left them, those, at least, which were allowed to remain as ruins. The houses were rebuilt, but the churches were not, and their bare, blackened walls, standing alone and devoid of any support or braces, rise to the height of, I should say, forty feet. I have examined them very carefully, and did not find a crack in them. Some of the towers were partially blown down then by powder, and look as if they were likely to tumble down at any moment. One, especially, seems threatening to fall with the wind. Yet they stand there as they have stood since 1854. These are forty-two miles from the proposed line of canal. In the town of Rivas, two and one-half miles from the canal, they have many stone houses, and about ten years ago they completed a stone church there, which has been building for thirty or forty years—one that would be a noteworthy church anywhere—and it has never received injury from earthquake shocks, nor have the stone houses about it. I had occasion to show to the United States Commissioners dams that had been built surely over 100

years ago, and are standing to-day, though not for any practical purpose; they have never been repaired, yet manifest no imperfections which can be detected by the closest examination. They were built originally for the purpose of damming up water to be used in the manufacture of indigo, and were abandoned, and have been standing there for over 100 years, perhaps."

These references show, not only that the locks and dams of the canal will not be affected by earthquakes, but that the country furnishes building materials of a superior quality.

A superior quality of lime, as evidenced by the existence to-day in an almost perfect state of preservation of indigo vats and dams over 100 years old, is obtainable at several places close to the line of the canal, and when properly manufactured there is no question but that it will prove equal, if not superior, to many cements in the market.

(*To be continued.*)

THE PARABOLIC SEMAPHORE.

By Prof. C. Herschel Koyl, Swarthmore College, Pa.

[*Read at the Stated Meeting, Wednesday, November 21, 1888.*]

Jos. M. Wilson, President, in the Chair.

Prof. Koyl:—Mr. President and Members of the Institute:

The object of a railroad signal being to show to an approaching engineman that the track is clear or the contrary, for a given distance, and the safety of trains and passengers depending upon the distinctness and the reliability of this signal, it is of the first importance that its indications should be unmistakable and itself impossible to confound with any other object along the track.

Originally the track was considered to be "clear" if no signal was displayed, while the exhibition of a disc or other board signified "danger," the appearance of the signal

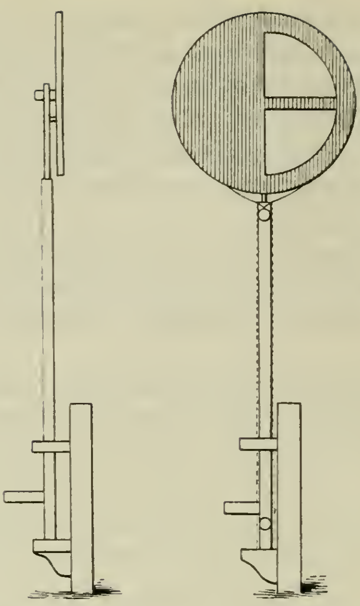


FIG. 1.—Safety. Danger.

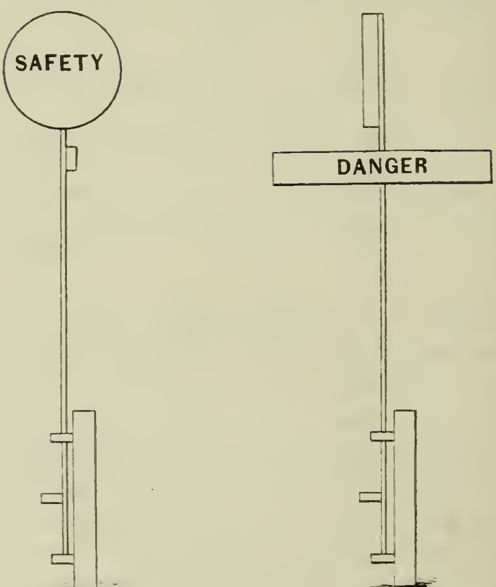


FIG. 2.

board being illustrated in *Fig. 1.* Later, a definite signal was given for "safety" as well as for "danger," *Fig. 2*, but then it sometimes happened that the signal which indicated "danger" on one road denoted "safety" on another, and such was the confusion and the desire for uniformity that when, in 1841, Mr. Gregory introduced the semaphore, *Fig. 3*, so superior to all other types of signals in its easily recognizable form and in being always visible—horizontal for

FIG. 3.

"danger" and dropped to 45° for "safety"—it began immediately to supersede all others, and is now almost the only day-light fixed signal in use on well-equipped roads.

But the difficulties attending night signals are still so numerous from the multiplicity along the track of other lights resembling those of the signal in form and color, *Fig. 4*, that the engineman can with extreme difficulty distinguish his own light, and for some years there has been a desire for a night semaphore, identical with the day signal, *Fig. 5*. Attempts have been made to illuminate the semaphore by placing a reflector along its centre, and the lamp in front; but when light from a lamp falls upon this flat surface, so much

is lost that not enough is left on the track to make the signal visible at a sufficient distance; and when detached pieces of reflector are set at different angles along the arm the apparatus becomes too cumbersome and fragile for use.

It is well known, however, that if light from the focus of a paraboloid falls upon the curve, it is from all points

FIG. 4. Railroad Signal on the Right.

reflected in lines parallel to the axis of the paraboloid, and a knowledge of this has been utilized in solving the question of a night semaphore. The arm is bent to a parabolic curve, presenting to a front view the ordinary dimensions of 5 feet 6 inches in length from the axis to the end of the blade, and 11 inches in width, and having a reflector

of silvered glass 4 inches wide along the centre from end to end. This is mounted in the ordinary casting which supports the semaphore arm and rotates about the axis in the post, which is also the axis of the paraboloid, in the focus of which the lamp is placed (*Fig. 6*).

Were the parabolic reflector of plane glass, the rays of

FIG. 5. Railroad Signal on the Right.

light would be almost absolutely parallel and could be seen only on a straight track; but in many cases a signal is approached around a curve, and it is necessary to diverge the light sufficiently to meet the requirements of such cases. It is accomplished by corrugating the reflector very slightly at right-angles to the directions in which the divergence is

required. For instance, to diverge the light laterally 16° from the direction of the axis requires the surface of the glass to make an angle of 8° with the parabola, and this is attained at blending intervals for both directions from the axis and for any intermediate degree of divergence by a wave surface, shown in section in *Fig. 7*, in which, if the

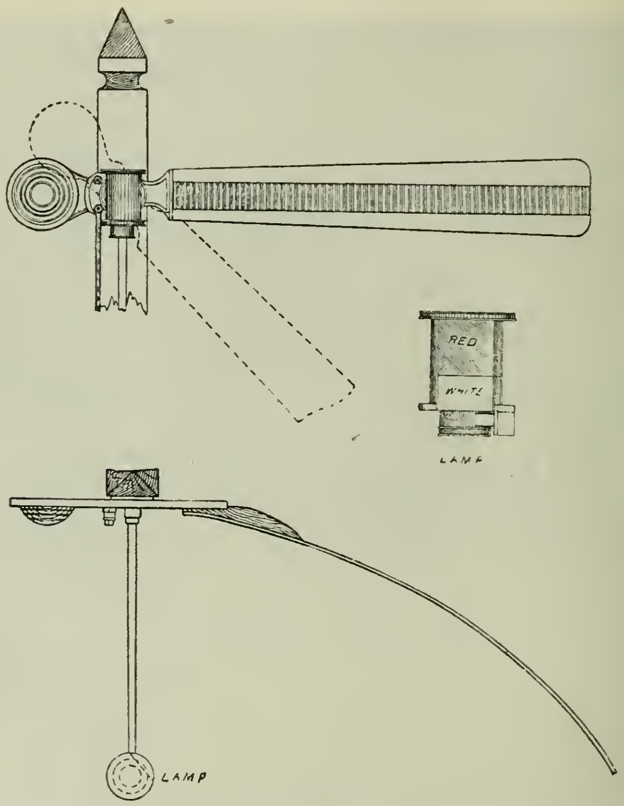


FIG. 6. Elevation and Plan.

wave-length be $\frac{3}{8}$ inch, the amplitude must be $\frac{3}{8}$ in. $\times \sin 4^\circ =$ approximately $\frac{1}{100}$ of an inch; and vertical divergence is gained by a wave surface at right angles to this, so that when one is superposed upon the other, divergence in all directions is the result. This makes an almost perfect position signal, giving a brilliantly-illuminated semaphore, when horizontal or when dropped.

But from the earliest days of railroading a *red* light has been the danger signal on posts, on switches, on the rear of trains, and in hand-lanterns, while a white light has always signified safety, so that the almost second nature which regards a red light as the only danger signal at night would prevent the use of any position signal which did not also show red for danger; and in the case of the parabolic semaphore, the upper half of the lamp is made red, and the lower part clear or green, so that the arm when horizontal appears red, and when dropped white or green, as the case may be.

During the day as well, the parabolic semaphore is also a color signal, for when horizontal, nothing is seen but the

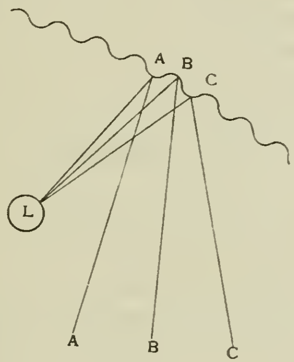


FIG. 7.

red frame and, when dropped, nothing but the glass brilliantly illuminated by the white sky.

The result is a semaphore which presents the same appearance by day and by night, which combines the qualities of a color signal with those of a position signal, which is not mistakable for any other light along the track, and the absence of which, therefore, from an accustomed place, should any accident happen to the lamp, would be immediately noticeable.

It is adapted to existing conditions because the arm is made to fit the castings at present in use and no further trouble or change is necessary than to remove the old board and put this in its place, fixing the lamp upon a

bracket in front. The reflector is of glass, with silver (not mercury) on the back, and therefore will not lose its reflecting power by exposure to the weather.

The advantages of the system may be summarized as follows:

(1) The semaphore is the standard day signal, and there is therefore no other night signal, the general introduction of which would render identical day and night systems.

(2) No other *form* of semaphore is known which will give enough light to be visible at the distance required by fast trains.

(3) No night signal would conform to well-established railroad rules which did not also show red for danger.

(4) No reflector, other than silvered glass, will stand exposure to the weather.

(5) No other known signal can be fitted to existing castings and equipment.

HELIOCHROMY.

BY FRED. E. IVES.

[*Read at the Stated Meeting, Wednesday, November 21, 1888.*]

JOS. M. WILSON, President, in the Chair.

MR. IVES: In my lecture, on "Some Recent Advances in Photography," delivered before this INSTITUTE in February last, I briefly described and illustrated a method devised by me for producing photographs in natural colors. I now have illustrations of the process, comprising a sufficient variety of subjects to more fully demonstrate its capabilities and value.

I claimed for this process that, unlike any similar process yet suggested, it was based upon a true conception of the nature of light and color vision, and was a strictly scientific method of accomplishing the object sought after—which is to produce, by an automatic process, pictures which counterfeit not only the light and shade, but also the colors of all objects which may be photographed.

I explained how some others who experimented in this direction failed, because they built upon the false theory that there are only three primary spectrum colors. I recognized the fact that there are, strictly speaking, thousands of primary spectrum colors, but also that all colors, whether simple or compound, may be counterfeited to the eye by means of three type colors, separate and mixed in different proportions. I assumed that we might counterfeit all the colors of nature in a photographic picture, by making each ray of simple color select automatically, in the operation of the picture-making process, such a type color or mixture of type colors as will counterfeit it to the eye, and showed how this can be accomplished by means of photographic plates made sensitive to all colors, and exposed through compound light filters, which are suitably adjusted by experiment upon the spectrum itself.

For the mechanism of the process, and some demonstrations, I refer to my original communication, which appeared in the JOURNAL OF THE INSTITUTE in May. I believe the problem had never before been stated with reference to the possibility and necessity of representing most of the primary colors by color mixtures, which, though not the same, produce the same color-sensation.

In order to make clear the fact that my plan of operation is in accordance with what is now recognized as the true theory of the nature of light and color-sensation, I make the following quotations from a recently published text-book on *Color*, by A. H. Church, M.A., London:

"Young's theory does not assume the existence of three primary colors, but of three primary color-*sensations*; a very important distinction.

"Every ray of differing refrangibility in the visible part of the spectrum is in one sense a primary color, for it is simple, and excites a definite sensation. But there are many reasons, mainly connected with the structure and functions of the eye, which have led to the selection of certain colored lights—generally three in number—as yielding primary color-*sensations*. This primariness is then not objective, but subjective in respect of human vision.

"Young's theory of color-perception amounts essentially to this, that in each elementary part of the retina of the eye there is, at least, one set of three different nerve fibrils, each of the three fibrils of a set being especially adapted for the production of its own specific color-sensation, yet in a less degree of the two others. Thus the receptive structure of the retina as a whole may be said to consist of an immense number of nerve fibrils of three orders; what we may call red fibrils being particularly acted upon by such long light waves as those in the red, but being also stimulated in a minor degree by the shorter waves in the green, and still less by those in the blue; the green fibrils will respond most actively to green waves, and in some measure, also, to red and to blue waves; while the blue fibrils will be most excited by the blue rays, though not uninfluenced by green and even by red rays.* It follows that when all three kinds of nerve fibrils are equally and simultaneously affected, the complex sensation of white light alone is produced.

"Colored lights may be, and often are, compound, sometimes consisting of two, and often of many more differently-colored elements, although the eye recognizes but a single color in the complex ray. A striking instance is afforded by yellow. There is an elementary yellow in the solar spectrum lying on the green or more refrangible side of the line *D*. By no contrivance can we optically decompose this spectral yellow, to which belongs a definite wave-length. But there are many compound yellow lights—lights which give us, as the sum of the simultaneous visual impression of their several components, a sensation of yellow not to be distinguished by the brain from the simple yellow of the spectrum. Such a compound yellow may be formed by throwing on the same portion of a screen a part of the red light and a part of the green light of a pure spectrum.

* "Helmholtz remarks, that the choice of these particular colors is somewhat arbitrary, and that any three could be chosen, which, when mixed together, would furnish white light. If, however, the end and middle colors of the spectrum (red, violet and green) are not selected, then one of the three must have two maxima, one in the red and the other in the violet; which is a more complicated, but not an impossible supposition."

Similarly there is a pure and simple blue in the spectrum, but a blue indistinguishable from this in hue may be obtained by mingling green and violet light."

Now, although I originally worked out my process on the simple plan of making each primary ray of spectrum color select from and combine three pigment colors to counterfeit it, it becomes evident that in accomplishing this I might have produced one negative by the action of solar rays nearly in proportion as they excite the "red nerve fibrils" of the eye, another in proportion as they excite the "green fibrils," and another in proportion as they excite the "blue fibrils." I did not do this at once, but after experimenting with several sets of reproduction pigments, adjusting color-screens so that I could make the process counterfeit the spectrum with either set of pigments, I finally adopted reproduction colors which call for negatives of the spectrum showing curves of intensity approximating to the curves in Maxwell's diagram, illustrating the action of the spectrum upon the different sets of nerve fibrils. These reproduction colors are certain shades of red, green and blue light, or their complementary colors in pigments, which approximate to Prussian blue, magenta red and aniline yellow, the first two of so light a shade that it is necesary to superimpose one upon the other to obtain a full violet blue, the blue upon the yellow to obtain green, and the magenta upon yellow to obtain red.

When I made my first communication upon the subject, I assumed, with Helmholtz, that there might be some latitude in the selection of type (reproduction) colors, and therefore did not commit myself to the use of any particular ones, but merely showed how I would produce at will negatives of the spectrum having any curves of intensity that might be required in order to secure the proper distribution of such colors or pigments as were selected. The adoption of reproduction colors corresponding to what are now recognized to be the primary color-sensations, has made it possible for me to state more definitely my mode of procedure, as above.

What I claim as new and original in my method is (1) the

production of heliochromic negatives by exposing color-sensitive plates through compound color-screens, which have been adjusted to secure negatives showing curves of intensity which bear a certain definite relation to the colors employed to produce the heliochromic pictures; and (2) the production of heliochromic negatives by a procedure calculated to yield negatives of the spectrum showing curves of intensity which probably correspond to the action of the spectrum upon the sets of nerve fibrils.

Admitting the theoretical soundness of my mode of procedure, which I believe I have fairly demonstrated, there remains only the question of practicability and commercial value to be considered. The process is practicable, if the same operations, repeated in the same manner, can be relied upon to produce pictures which counterfeit the light and shade and color of all objects. Three subjects, which I shall show to-night, a delicate oil-painting, a brilliant Prang chromo and a beautiful sea-shell, were made with the same light, same camera, same preparation of sensitive plates, same set of color screens, same relative exposures and same development. They show a very great variety of colors, mostly compound in the painting and chromo, but pure spectrum colors in the sea-shell; yet the colors of all are alike faithfully counterfeited to the eye. Although there should be no question of the fact, I will here state that these finished results have been obtained without any retouching or artificial manipulation whatever.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, December 18, 1888.*]

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, December 18, 1888.

Mr. J. H. EASTWICK, President, in the Chair.

Members present: Dr. L. B. Hall, Dr. S. C. Hooker, Dr. H. W. Jayne, Messrs. Luthy, Macfarlane, Chase, Bower, Pemberton, Matos and Palmer.

The bills for printing were approved, and ordered to be paid.

Mr. John G. Bullock's resignation as a member of the Section was accepted.

Mr. Philip E. Clarkson, of Quaker City Dye Works, and Mr. Jacob Lichenheim, 1614 North Tenth Street, Philadelphia, were elected full members of the Section.

The following gentlemen were nominated for membership in the Section: Mr. F. C. Lewin, 1011 Spruce Street, Philadelphia; Mr. C. V. Petraeus, 231 South Front Street, Philadelphia; Mr. R. E. Fisher, 2239 St. Alban's Place, Philadelphia; Dr. Wm. H. Greene, 204 North Thirty-sixth Street, Philadelphia; Dr. Geo. A. Koenig, University of Pennsylvania, Philadelphia; Mr. Henry C. Lea, 2000 Walnut Street, Philadelphia; Prof. Henry Morton, Stevens Institute, Hoboken, N. J.

The following gentlemen were elected officers of the Section for the year 1889:

President, Mr. H. Pemberton, Jr.

Vice Presidents, Dr. S. C. Hooker, Mr. T. C. Palmer.

Secretary, Dr. Wm. C. Day.

Treasurer, Dr. H. W. Jayne.

Conservator, Dr. Wm. H. Wahl.

Mr. H. Pemberton, Jr., presented a communication from Dr. Wm. H. Wahl, Secretary of the INSTITUTE, concerning the publishing of papers read before the Section, in the JOURNAL OF THE INSTITUTE, simultaneously with other journals to be selected by the Section.

The President appointed as a committee to confer with Dr. Wahl on this matter, Mr. H. Pemberton, Jr., Dr. S. C. Hooker.

The following were appointed a committee to revise the membership list, and re-arrange the By-Laws of the Section: Mr. T. C. Palmer, Dr. H. W. Jayne, Mr. R. L. Chase.

Mr. O. Luthy exhibited a piece of the mineral eudialyte, from Greenland. This species is a prominent source of zirconium. Mr. Luthy stated that it had lately been found in large quantities in the above country, near the cryolite locality. Twenty tons had been shipped to Europe at one time. Dr. Jayne stated that this material is largely imported into this country from Sweden, being used in the manufacture of the films for the Welsbach gas lights.

Mr. Chase remarked that there has been much difficulty in getting a film for these lamps that will be durable. Cases have been known where these films were broken by the slight jar caused on a floor above by falling boxes.

Dr. Hooker remarked that the burette, exhibited by him in October, was thought at the time to be new. He had since had his attention called to the figure of a burette almost identical with this.

Dr. Hooker showed several samples of sugar said to have been refined by the aid of electricity. These samples are different in appearance from any sugars heretofore in the market, but Dr. Hooker was of the opinion that much nonsense had been published by the non-scientific press on the subject of sugar-making by electricity; that it would be very easy to give granulated sugar this same appearance by caking and passing through a sieve. Mr. Luthy had also investigated the matter, and had concluded that this so-called electrically-refined sugar is only ordinary sugar specially prepared.

Mr. Macfarlane showed a copy of the souvenir published by Meister, Lucius & Bruening, on their twenty-fifth anniversary, July 2, 1888. This souvenir contains statistics of the growth and present dimensions of the great color works of this house, bird's-eye views of the buildings, maps of the enclosures, etc.; also a very beautiful spectrum of colors (all artificial) dyed on yarn.

Dr. Hooker showed a sample of saccharine, and remarked that many tests had been proposed for its detection, but that the most reliable one was based on the following principle:

The suspected substance is treated with ether, the extract evaporated and the residue fused with caustic potash, when if saccharine is present, salicylic acid is formed, and may be detected by the violet color formed with ferric chloride.

Dr. Jayne mentioned the fact that the use of saccharine had been prohibited in France for certain purposes, for revenue reasons. The same is true in England. Dr. Hooker stated that the evidence seemed to show that saccharine impairs the digestive process. Dr. Hall thought that this was doubtful, German authorities of high rank altogether dissenting.

Adjourned. T. C. Palmer, *Secretary.*

(Subject to Revision.)

On the DETECTION of FAHLBERG'S SACCHARINE.

By Samuel C. Hooker, Ph. D.

[*To be read January 15, 1889.*]

A test has been recently described by E. Börnstein * for the detection of saccharine, based upon the supposed formation of a sulpho-phtaleïn. Saccharine is heated with a slight excess of resorcine and a few drops of concentrated sulphuric acid; on the addition of water a solution is obtained which fluoresces strongly when rendered alkaline.

I wish to point out that this test is rendered valueless by an observation I made about a year ago. Resorcine, when treated with sulphuric acid *alone*, gives apparently precisely the same reaction as that which Börnstein describes as characteristic of saccharine.

The reaction has unfortunately been already used in several instances which have come under my notice, and the presence of saccharine inferred in cases in which it was probably altogether absent.

It has long been known that resorcine, when heated with zinc chloride, also gives rise to products which fluoresce strongly.

A RAPID COLORIMETRIC METHOD for the ESTIMATION of NITRATES in NATURAL WATERS.

By Samuel C. Hooker, Ph. D.

[*Read October 21, 1888.*]

It was long ago observed by Graebe and Glaser,* that the addition of oxidizing agents, in small quantity, to carbazol dissolved in concentrated sulphuric acid, gave rise to an intensely green solution. Up to the present time no useful application has been made of this reaction.

* *Berichte*, **21**, 488, R.

In devising a process for the rapid estimation of nitrates in the minute quantities in which they occur in natural waters, I have taken advantage of this property of carbazol. I have ascertained that under certain conditions, water containing as little as two parts of nitric acid per million gives a distinct reaction with the sulphuric-acid solution of carbazol: and that within certain limits the intensity of the color produced may be taken as the measure of the nitric acid present.

The estimation briefly described, omitting the necessary precautions, is conducted as follows: A measured quantity of the water, 2 cc. or less according to circumstances, is mixed with about 4 cc. of concentrated sulphuric acid, and when this has cooled a small quantity of sulphuric acid containing carbazol in solution is added. The green color produced is compared with that given by standard solutions of potassic nitrate, under precisely similar conditions, until the color is closely matched. The estimation is very rapidly effected, and provided the water contains as much nitric acid as two parts per million, as is very often the case, it need not be concentrated by evaporation.

The details of this process, together with the precautions to be taken in the presence of chlorides, nitrites, etc., will be described shortly in a paper giving the results of analyses made with the object of testing the delicacy of the method.

In conclusion, I would suggest the possibility that other compounds, diphenylamine or brucine, for instance, may prove as serviceable as carbazol for the purpose here described.

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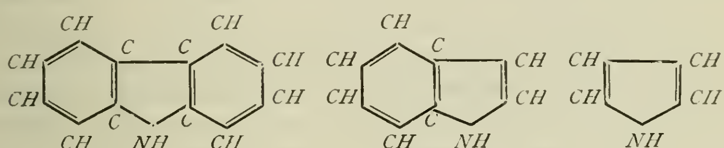
* *Ann.*, **163**, 347.

ON THE RELATIONS EXISTING BETWEEN CARBAZOL AND PYRROL.

BY SAMUEL C. HOOKER, Ph. D.

[*To be read January 15, 1889.*]

The theoretical relation existing between carbazol, indol and pyrrol is well shown by comparing their formulæ as follows:



Carbazol. Indol. Pyrrol.

The analogy existing between indol and pyrrol has received important experimental demonstration from the researches of v. Baeyer, E. Fischer,* and Ciamician,† but up to the present time no material evidence has been accumulated to show that a similar relation exists between carbazol and pyrrol. The formation of carbazol from thio-diphenylamine ‡ by the action of copper furnishes some proof in support of the formula given above; but as this is the only reaction clearly tending to show that carbazol is a di-ortho derivative of diphenyl, and, therefore, that it contains the pyrrol ring, further evidence in the same direction appears desirable.

In making the experiments which led up to the facts here recorded, I hoped to find points of resemblance between carbazol and pyrrol for which the >NH group alone, independent of the pyrrol ring, would not account, and thus to confirm indirectly the above formula of carbazol.

Runge, the discoverer of pyrrol, observed that its vapor in contact with pine moistened with hydrochloric acid,

* *Ber. d. chem. Ges.*, **19**, 2,988.

† *Ibid.*, **19**, 3,028.

‡ *Ibid.*, **20**, 232.

colored the wood intensely red. Von Baeyer subsequently described this reaction as being very characteristic of indol. It is interesting, therefore, to find that carbazol reacts similarly, though not so readily. In order to observe the reaction, soak the wood—an ordinary match-stem answers admirably—for a second or two in a hot alcoholic or acetic-acid solution of carbazol, and then thrust it into the neck of a bottle containing concentrated hydrochloric acid, so as thoroughly to expose it to the action of the gas without bringing it in contact with the acid solution. The red color soon develops, and slowly increases in intensity. The shade is precisely similar to that produced by pyrrol.

Since carbazol may be regarded as a derivative of indol in which the two carbon atoms of the indol ring are connected with the group C_4H_4'', this observation appears directly to contradict one of the deductions made by Emil Fischer* in the course of his study of indol derivatives. "The fir-wood reaction," he says, "no longer occurs when both the carbon atoms of the indol ring are connected with alkyls."

It seemed necessary, therefore, to confirm my results by substituting synthetical carbazol for that extracted from coal tar, with which I first obtained the reaction. In spite of careful purification, it is conceivable that the coal-tar carbazol might still retain traces of foreign substances capable of imparting to it the power of coloring the wood.

Through the kindness of Dr. A. Goske in forwarding to me a sample of carbazol recently obtained by him† by the action of copper on thio-diphenylamine, I have been able to confirm the results of previous experiments in a satisfactory manner.

It seems possible therefore that the di-alkyl derivatives of indol which do not, according to Emil Fischer, give the fir-wood reaction when the test is made in the usual way, may do so if the conditions of the experiment are somewhat varied.

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* *Ber. d. chem. Ges.*, **19**, 1,570.

† *Ibid.*, **20**, 232.

CARBAZOL AND ISATIN.

The behavior of thiophene (and furfuran) in forming coloring matters with isatin and ortho-diketones apparently similar to those of pyrrol, makes it probable that in such reactions the $>NH$ group of pyrrol takes no part. Consequently, in the case of carbazol, as all the hydrogen atoms of the pyrrol ring, excepting that of the imide group, are already substituted, it is not to be expected that any similar coloring matters can be formed. For this reason I was surprised to find that the behavior of carbazol and isatin in the presence of sulphuric acid is such as to strongly suggest the indophenine reaction.

On adding concentrated sulphuric acid to carbazol and isatin, an intense blue color is developed as the substances dissolve. The reaction is extremely characteristic and can be used as a delicate test for the recognition of carbazol. The blue color of the solution does not appear to be affected by slightly warming, and even after standing some hours its intensity had not materially diminished or its color otherwise changed. Water precipitates an indigo-blue substance which very rapidly becomes lighter in color. In order to avoid this change, attempts were made to extract the blue coloring matter from the acid solution without the addition of water, by agitation with various solvents. These experiments proved unsuccessful, and the further study of the compound was abandoned.

Although the above is very like the indophenine reaction and its apparently analogous reaction in the case of pyrrol, I am inclined to believe, for considerations already mentioned, that the similarity is apparent only and not real. Diphenylamine gives no reaction with isatin under the same circumstances.

Since diphenylene-oxide and diphenylene-sulphide are probably related to furfuran and thiophene, respectively, in the same way as carbazol is to pyrrol, it seemed of importance to ascertain whether these substances also behaved similarly with isatin. I was unable to obtain any reaction with diphenylene-oxide, and consequently it is probable that diphenylene-sulphide also will be found indifferent.

CARBAZOL AND QUINONE.

The compounds produced from pyrrol and benzoquinone have no corresponding members in the thiophene series, and would appear to be directly or indirectly dependent upon the >NH group for their existence; it therefore seemed possible that carbazol and benzoquinone might react with the formation of similar compounds.

If a small quantity of sulphuric acid, diluted with one or two volumes of acetic acid, is added drop by drop to an acetic-acid solution of carbazol and benzoquinone, an intense carmine red solution is produced, which passes into a reddish-violet as the quantity of sulphuric acid is increased. Water precipitates from this solution a substance of the same color, which dissolves very readily in ether, chloroform and alcohol.

On the addition of crystals of quinone to carbazol dissolved in concentrated sulphuric acid, an intense green color is imparted to the solution. Hence, according to the strength of the acid used, a reddish-violet or a green solution is obtained.

Similarly Victor Meyer and O. Stadler* haves hown that benzoquinone reacts with pyrrol in two distinct ways. If aqueous solutions of the two are mixed, a violet coloring matter is produced, whereas in the presence of dilute sulphuric acid a green precipitate is formed. For purposes of comparison I repeated V. Meyer and Stadler's experiments. The violet coloring matter obtained dissolved in ether to a solution very similar in shade to that of the ethereal solution of the coloring matter from carbazol.

Before concluding that the formation of these compounds is in any way connected with the existence of the pyrrol ring, it seemed necessary to study the action of diphenylamine under similar circumstances. Sulphuric acid added to diphenylamine and quinone dissolved in acetic acid immediately colors the solution blue; on adding water, a violet substance is precipitated.

These reactions recall the coloring matters obtained by

* *Ber. d. chem. Ges.*, **17**, 1,035.

P. Greiff* by heating chloranil or quinone with methyl-diphenylamine and other amines with or without the addition of zinc chloride. The similarity existing between the method of formation and the shade of Greiff's coloring matters and the violet compounds obtained as above described from pyrrol, carbazol and diphenylamine, renders it extremely probable that in both cases the coloring matters are perfectly analogous, and that their formation in the case of pyrrol and carbazol depends upon the amine character of these substances, and not upon the presence of the pyrrol ring. This view, which could not, unfortunately, be substantiated by analysis, owing to the great instability of the pyrrol compound, receives support from the fact already alluded to that thiophene gives no coloring matters with benzoquinone.

With reference to the green solution formed on adding quinone to carbazol dissolved in sulphuric acid, it seems probable that in this case quinone plays the part of an oxidizing agent only, for the same green-colored solution is produced, as is well known, by the addition of oxidizing agents generally under similar circumstances. It occurred to me, therefore, as not unlikely that quinone acts merely as an oxidizing agent also, when in contact with pyrrol in acid solution, especially as V. Meyer and Stadler extracted hydroquinone in considerable quantities from the mother-liquor after the green compound had been filtered off. Confirmation of this view was obtained by reference to Anderson's† description of the properties of pyrrol. He states that ferric chloride causes a dilute hydrochloric-acid solution of pyrrol to turn first *green* and then black. He adds that platinic chloride and potassic bichromate produce a black precipitate with the same solution.

A few experiments soon proved that not only ferric chloride, but potassic chromate or bichromate, platinic chloride, potassic ferricyanide, and even potassic nitrite under certain circumstances, all give, when added in small quantity

* *Ber. de chem. Ges.*, **12**, 1,610.

† *Ann. Chem.* (Liebig), **105**, 354.

to a dilute sulphuric-acid solution of pyrrol, a green substance which passes more or less rapidly, according to the oxidizing agent used and the acidity and degrees of concentration of the solutions employed, into the black compound observed by Anderson. With tolerably concentrated solutions of the oxidizing agents, the transition is so rapid that the green color can be scarcely observed, even when the sharpest lookout for it is maintained throughout the experiment.

With a dilute solution of potassic chromate, the formation of the green substance may be readily seen, and the reaction compared with that of quinone. As it is not easy, however, to obtain the reaction at its best without a number of trials, I prefer to give the exact strength of the solutions which I found to give good results. Eight drops of pyrrol are dissolved in 10 cc. of water to which eight drops of sulphuric acid have been added. When this is mixed with an 0·1 per cent. solution of potassic chromate in equal volumes, the green color is almost immediately developed, and rapidly increases in intensity until the solution becomes perfectly opaque. At this stage three or four volumes of water are added. The diluted solution is green in color, and slowly deposits a dark green or black precipitate.

A very dilute aqueous solution of quinone behaves almost precisely similarly with the above solution of pyrrol, but the precipitate formed is at first much greener than when potassic chromate is the oxidizing agent used. It gradually darkens, however, and after some hours becomes almost black. If the green precipitate from quinone is washed with an 0·05 per cent. solution of potassic chromate, it is very rapidly blackened.

From these experiments it would appear extremely probable, therefore, that quinone does not condense with pyrrol in acid solution, but merely acts like other oxidizing agents.

The formation of green substances like the above is not confined to the action of oxidizing agents on carbazol and pyrrol. It has long been known that nitrous acid and other oxidizing agents added in small quantity to diphenylamine

dissolved in sulphuric acid, produce an intense blue solution from which water precipitates a green compound; this, like the corresponding compounds from carbazol and pyrrol, is insoluble in ether.

PYRROL AND PICRIC ACID.

The behavior of indol and carbazol in combining with picric acid suggested the idea that probably pyrrol would form a similar compound. On adding picric acid to an excess of pyrrol, a red color is at once developed; on warming, the picric acid is dissolved, and the solution, when cold, deposits beautiful red needles. Similarly, if picric acid and an excess of pyrrol are dissolved in alcohol, long red needles, half or three-quarters of an inch in length, can be readily obtained as the solution is allowed to evaporate. The compound is very unstable, and commences to decompose in the air as soon as the crystals are dry. Its fusing point is about 71°. Since the basic properties of pyrrol are very weak, and no well-defined salts have been obtained with acids generally, the above described compound must be considered as analogous to the picric acid compounds of the hydrocarbons. The relation of pyrrol to benzol, so often dwelt upon by Victor Meyer, is thus once again emphasized. Phenyl-pyrrol also forms an unstable compound with picric acid. The compounds of pyrrol and its derivatives with picric acid will be further studied, and an attempt will be made to analyze them.

[COMMUNICATION.]

FOR SEALING OF VOLATILE LIQUIDS IN GLASS TUBES.

GENTLEMEN: The following communication on "The Sealing of Volatile Liquids in Glass Tubes," may be found of general interest. In order that glass tubes containing very volatile liquids may be properly sealed, the temperature of the tubes and their contents must be so lowered that the vapor tension of the liquid is not greater than the

atmospheric pressure. This is accomplished by immersing the tube in a cooling mixture to within a short distance of the point at which it is to be sealed. A tube containing liquid sulphur dioxide may thus be sealed while it is surrounded by a mixture of ice and salt.

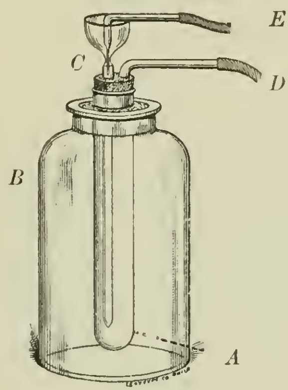
When the required temperature is below that of the ordinary freezing mixtures, advantage must be taken of the evaporation of liquid carbon dioxide or nitrous oxide at low pressures, and by care in manipulation it is then not difficult to seal tubes that are nearly filled with such volatile liquids as the two just named.

The tubes intended to contain such specimens, and which may be used to illustrate the phenomena of the critical condition and the precipitation of saturated vapors, must be made ready for sealing several days before they are to be filled, and carefully annealed in order that the glass may be prepared for the considerable pressure which it must sustain. Ordinary stout tubing with walls about two millimetres thick, and of five to seven millimetres internal diameter, may be employed. The piece selected is prepared by contracting the diameter to about two millimetres near one end, closing this end and blowing it into a funnel a little larger than necessary to hold all the liquid required to fill the tube. The other end of the tube is then sealed at the desired distance from the contraction—twenty centimetres is a convenient length. When the tubes have recovered from the effects of the heating, or immediately after they have been annealed in an oven, they are ready for filling and sealing.

The apparatus required for cooling the tubes during the operation is easily constructed, as shown in the accompanying diagram. A stout test tube, *A*, about twenty-five millimetres diameter, and of such length as is required by the tube to be sealed, passes through a flat cork in the mouth of a strong bottle, *B*, containing some pumice stone moistened with sulphuric acid. This test tube is half or two-thirds filled with liquid nitrogen monoxide or carbon dioxide, and about one-fourth as much ether is cautiously added. To the test tube is adapted a rubber stopper carrying the

tube C to be filled, the contraction at which it is to be sealed being about one centimetre above the level of the stopper, and a bent tube, D, the external end of which is connected with an aspirator.

The almost capillary extremity of a bent tube, E, is then passed through the contraction below the funnel, and through this the air is rapidly sucked from the tube as the liquid nitrogen monoxide is poured into the funnel. There must be sufficient space between the capillary tube and the walls of the contraction to allow the free descent of the liquid. When a sufficient quantity of liquid has been introduced, it is necessary to wait until the gauge of the aspirator



shows a constant pressure; the tube is then cut off at the contraction and sealed by directing on it the flame of a movable blast lamp. The tube D is then disconnected with the aspirator, and the sealed tube with the rubber stopper is carefully removed and placed vertically where its possible explosion on warming will do no harm. Pieces of bamboo cane, so cut that the joints form the bottom, make convenient receptacles for the tubes while they take the temperature of the room.

After the tubes have assumed the ordinary temperature, they should be gradually warmed to the highest degree to which they will probably be exposed, in order that there may be no risk in handling them.

If a mixture of nitrous oxide and ether be used for cooling, there should be no flame in the neighborhood of the recipient while it is open.

If the specimen be intended to illustrate the critical phenomena, the tube should be at least three-fourths filled with liquid before sealing. If it be designated to show the formaation of a cloud and the precipitation of liquid drops, it should not be more than one-third filled.

I am indebted to Mr. Thos. R. Harrison for valuable assistance in preparing several tubes of nitrogen monoxide in the manner described. Very truly,

WM. H. GREENE.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, December 1, 1888.

ABSTRACTS.

REDUCTION PRODUCTS OF HÆMATOXYLIN (J. Hegler. *Moniteur Scientifique* from *Jour. of Soc. of Dyers and Colorists*, **4**, 129). Many attempts have been made to reduce hæmatoxylin, without satisfactory results.

Fr. Reim found that this coloring matter was not affected by sodium amalgam or zinc and sulphuric acid. On heating it with zinc powder, he obtained a crystallizable body, suspended in an oily liquid, but in too small a quantity to analyze it. Heavy gases were evolved at the same time, arising from the decomposition products, which could not be condensed.

E. Erdmann and G. Schultz have obtained, by heating hæmatoxylin in closed tubes with hydriodic acid, a mixture of hydrocarbons, which are partly volatile in steam and partly soluble in benzene.

C. Dralle, in confirmation of Fr. Reim's results, has detected the presence of carbonic acid and resorcin in the products of distillation.

The author's attempt to reduce hæmatoxylin with zinc powder also gave too small amounts of product to analyze.

The author tried the acetyl derivative obtained by the action of acetyl chloride. One part of the acetyl derivative of hæmatoxylin was gradually heated with thirty to forty parts of zinc powder in a slender tube under the air pump. The distillation product obtained in this manner consisted of resorcin in aqueous solution and a yellow oil, with a characteristic smell.

The author tried to separate the different products by fractional distillation.

The body, which passes over above 300° C., is solid, yellow, soluble in alcohol, ether, glacial acetic acid and benzene.

From these solutions it crystallizes in small yellow needles, grouped in stars, which fuse at 80°. This body forms a compound with picric acid which decomposes at 105°.

Three analyses gave the following results :

	Found.			Calculated for.		
	I.	II.	III.	$C_{15}H_{16}$	$C_{15}H_{14}$	$C_{16}H_{18}$
C.	90·82	90·58	90·71	91·82	92·78	91·42
H.	7·99	7·74	7·88	8·17	7·21	8·57

Owing to the small amount of substance obtained, it was not possible to have the hydrocarbon free from a small amount of a substance containing oxygen.

The vapor density determined by V. Meyer's method in sulphur vapor, together with the analysis, indicate the body to be a hydrocarbon $C_{15}H_{16}$, which is probably a homologue of diphenyl.

Vapor density—

Found.	Calculated for.		
	$C_{15}H_{16}$	$C_{15}H_{14}$	$C_{16}H_{18}$
6·88 and 6·72	6·79	6·72	7·27

The fraction between 200° and 300° passes over mostly at 250°–260°. It is a yellowish oil, with a strong smell, which turns brown in the desiccator over sulphuric acid. It is insoluble in alkalies, which is contrary to the character of a phenol.

On analysis it gave the numbers—

	I.	II.
$C =$	88·24	87·93
$H =$	8·04	8·20

Its vapor density in sulphur was 5·59.

The portion passing over between 100° and 200° is a volatile liquid, with a penetrating odor, and is insoluble in alkalies. Unfortunately the author had too little substance to determine its vapor density.

On analysis the results indicated that it had the formula $C_{10}H_{14}O$.

	Found.		Calculated for.
	I.	II.	$C_{10}H_{14}O$
C.	80·79	79·79	80·00
H.	8·94	8·92	9·33

H. T.

On the Detection and Estimation of Magenta in Orchil and Cudbear. By Christopher Rawson (*Journal of Soc. of Dyers and Colorists*, **4**, 68).—The author has found such difficulties in the use of previously-published processes, that he suggests the following based upon the complete precipitation of the coloring matter of orchil or cudbear in an aqueous and alcoholic solution by acetate of lead, followed by an excess of ammonia. Magenta base under the same conditions remains in solution. From one to two grains of cudbear (or an equivalent amount of orchil liquor) are boiled with 50 cc. of alcohol, and afterwards diluted with 100 cc. of water; 15 to 20 cc. of a strong solution of basic acetate of lead (sp. gr. 1·25) are then added, followed after stirring by a similar quantity of strong ammonia. The mixture is filtered, and if the amount of magenta present is to be *estimated*, the precipitate is washed with a solution containing one part of ammonia, five parts of alcohol and ten parts of water; otherwise the washing may be

neglected. With pure cudbear, the filtrate is quite colorless; if magenta be present, it is either colorless or pink, according to the amount of ammonia present in the solution. The liquid is then acidulated with acetic acid, when the presence or absence of magenta is at once made apparent; in the case of pure cudbear or orchil, the solution remains colorless; whereas, if a salt of rosaniline be present, the well-known color of magenta is immediately developed. By means of this method one part of magenta in 100,000 of cudbear can be detected with certainty.

For determining the *amount* of magenta present the author suggests a calorimetric method, in which the filtrate or an aliquot portion of it is compared with a standard solution of magenta.

The method is also applicable to the detection of methyl violet and safranine. The base of the latter is much more soluble in ammonia than those of methyl violet and magenta.

The three coloring matters are distinguished from one another on the addition of acetic acid to the ammoniacal filtrate, the solution becomes of a bluish violet tint, if methyl violet be present. Under the same conditions, solutions of safranine and magenta are pink or bluish red. Strong ammonia decolorizes methyl violet and magenta, whereas it produces little or no effect upon a solution of safranine. Strong hydrochloric acid added to a solution of safranine, changes the color to a blue; solutions of magenta and methyl violet become, with the same reagent, of a pale yellow color.

The azo or oxy-azo dyes, as rocellin, orchil red, etc., when present in cudbear, may usually be detected by sprinkling a little of the sample on the surface of concentrated sulphuric acid, with the formation of a characteristic colored streak, which may be either green, blue or violet. To detect other adulterations, or in cases of doubt, one should resort to dye tests. H. T.

ON THE PREPARATION OF ANHYDROUS MAGNESIUM CHLORIDE.—Walther Hempel (*Berl. Ber.*, **21**, 897). Anhydrous magnesium chloride is ordinarily made by the addition of ammonium chloride to the solution of the salt and the decomposition of the ammonio-magnesium chloride so formed by heating to about 460°. The author has found that the solution of magnesium chloride may be evaporated without decomposition and formation of basic salt, provided the operation be performed in an atmosphere of hydrochloric acid. The addition of ammonium chloride is unnecessary, and there is a great economy of heat. W. H. G.

BOOK NOTICES.

SOAPS AND CANDLES. By James Cameron, F.I.C. Philadelphia: P. Blakiston, Son & Co. 1888. Price, $2.25.

Dr. Johnson once remarked to a certain Mr. Cambridge: "Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information upon it. When we inquire into any subject, the first thing we have to do is to know what books have treated of it." This remark

applies with much more force to-day than it did a century ago when it was uttered. But to no branches of knowledge is it so applicable as it is to those that are of a scientific nature. Indeed, it is becoming quite a serious problem to know how to separate and disentangle any desired information from the huge mass of facts contained in the volumes of the many scientific journals now published. The editors of these journals recognize this difficulty, and, accordingly, give not only an index of each number and of each volume, but also publish at intervals of a few years an index of the series of volumes that has appeared in the interim. This is true, for instance, in the case of *Dingler's Journal*, of *Silliman's Journal*, and of others that might be mentioned. The preparation of such indexes is tedious and expensive, and would, therefore, be likely to be shirked were it not that the necessities of the case actually force the editors to take the step. They have been obliged to do so with the journals, not only because the latter contain an extraordinary variety of information, but also for another reason. These journals are to the scientific man what the daily newspapers are to the general public. They present the very latest information; they give it in its discursive and formative stages; they contain an abridgment, at least, of all the new ideas propagated, of all the inventions made, of all the patents issued that come within their respective departments of science. They are away and far ahead of any other vehicle of knowledge, and frequently lead the encyclopædias, treatises, manuals and text-books by a good decade at least. It is not too much to say that many of the facts and discussions appearing in the journals and technical papers of to-day will not be embodied in the text-books until the beginning of the next century.

The important position, therefore, held by this form of scientific literature, forces the editors to publish frequent and copious indexes, covering back volumes, as already described. But there are very few writers of *books*, who follow the example of these editors. Imitation is the sincerest form of flattery, and the authors of the countless scientific manuals show a sincerity in the admiration for their predecessors that is beautiful to contemplate. The amount of copying from one text-book into another by the writers on mechanics, physics, chemistry, electricity, or astronomy is, indeed, marvellous, and the regularity and precision with which they keep behind the times in stating the facts is also a matter of wonder. But the especial weakness in compositions of this character is the entire absence of references to the original papers from which the extracts are taken.

Ganot's Physics, for instance, is a good treatise; an excellent one. But how much more valuable would the book be to the scientific worker, if the editors had referred the reader to the time and place in which the investigations and experiments they only outline are given full and complete.

We have dwelt upon this matter at some length, because Mr. Cameron's book is a marked exception to the class of books above described. There is hardly a page in it that does not contain, as foot-notes, references to chemical, pharmaceutical or medical journals, to standard works, to lectures, to exhibition reports, or to English, German or United States patents. The book shows the results of wide reading and of careful collection of data, and in the com-

paratively small space of some 300 pages the reader is directed to a thousand sources of information of a most valuable kind. There are many illustrations of apparatus and machinery; tables showing strength of solutions, properties of oils, relation between degrees Baumé and specific gravity, and so on. These last tables are incorrect. In fact, in nearly all English books the densities by Beaumé's hydrometer are incorrect. The reason of this probably is that the English use this hydrometer very little, preferring Twaddle's. It should be borne in mind, also, that the gallons used in the various recipes are English gallons, and therefore of twenty per cent. greater capacity than ours (ten pounds of water as against eight and one-third).

We have not space here to give a detailed analysis of the book, but can recommend it to any one interested in the manufacture of soap or of candles, as a work that will prove most useful to him. H. P., Jr.

Hints on House Building. By Robt. Grimshaw. New York: Practical Publishing Company. 1887.

This is a little manual of notes, compiled by the author during his active experiences, and, as the name indicates, it contains many brief but useful suggestions which will be found to add materially to the comfort and convenience of the home, and which might otherwise be overlooked at a critical moment.

The book is not indexed, but each paragraph is prefaced by its subject matter in small capitals, and as there are but thirty-two pages duodecimo, it is not difficult to find a hint relative to some special feature. It would seem to us, however, to be an improvement, had the subjects been arranged with some approximation to an alphabetical order. L. M. H.

An Index to Engineering Periodicals, 1883–1887. By Francis E. Galloupe, M.E. Boston: Published by the *Engineering News* Publishing Company, New York. 8vo, cloth, 294 pp. $2.

The title of this work is sufficiently explicit. It is only necessary to add the names of the periodicals which have been indexed, during these five years, to give its scope. They are: *Eng. News*, *Iron Age*, *Mechanics*, *Am. Eng.*, *Sanitary Eng.*, *Eng. and Build'g Record*, *Railroad Gazette*, *Van Nostrand's Eng. Mag.*, *R. R. and Eng. Journal*, Journal of the Franklin Institute, *Street R'y Gazette*, *Electrician and El. Eng.*, *Elec. Rev.*, *Elec. World*, *Sci. Am. Supplement*, *The Locomotive*, *Society of Arts Proceedings*, Mass., *Engineering* (London), *The Engineer* (London).

Although comprehensive, the list is by no means complete, yet the author has rendered an invaluable work to the scientific professions and to the arts by thus placing it in the power of those engaged in investigations and research to save much time and trouble for a trifling expense. The subjects are classified and arranged in alphabetical order, making the reference easy. The book is indispensable, and the only regret is that its scope is not greater, still it is a move in the right direction, which should be continued by annual appendices, if possible, to keep it up to date. L. M. H.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Adam, Son & Co. Private Telegraphic Code. From Mr. S. H. Needles.

Alabama. Report of the State Board of Health for 1887.
Transactions of the Medical Association of the State for 1888.
From the State Health Officer.

Almanaque Nautico para 1890.
From Instituto y Observatorio de Fernando.

American Historical Association. Announcement and Programme of the Fifth Annual Meeting. From the Association.

American Water Works Association. Eighth Annual Meeting.
From the Association.

Baker, Henry B. Malaria and the Causation of Periodic Fever.
From the Author.

Baltimore. Annual Report of the Health Department for 1887.
From the Secretary of the Department.

Bayles, J. C. Spirally-Welded Tubing.
Spiral Weld Tube Company. Announcement.
From Mr. George Burnham, Jr.

Brooklyn Library. Bulletin No. 26. 1888. From the Library.

Bullock & Crenshaw. Price List of Chemicals. Catalogue of Apparatus.
From Bullock & Crenshaw, through Mr. Francis Leclere.

Bureau of Labor and Industrial Statistics, Wisconsin. Third Biennial Report. From Frank A. Flower, Commissioner.

Caligraph, The. Announcements, etc.
From the American Writing Machine Company.

Candee Journal Bearing Company. Prospectus.
From W. L. Lance, President.

Census, U. S., Tenth Reports. Vols. 17, 19, 21 and 22.
From the Department of the Interior.

Connecticut Legislative Documents, 1886 and 1888.
From the State Librarian.

Connecticut. State Board of Health. Sixth, seventh, eighth and tenth Annual Reports. From the Board.

Cowles Electric Smelting and Aluminium Company. The Alloys of Aluminium and Silicon. From the Company.

Department of Agriculture, U. S. Botanical Division. Bulletin No. 7.
Division of Chemistry. Bulletin No. 19.
Division of Entomology. Bulletin No. 5.
Report of the Statistician, No. 57.
From the Department.

Department of the Interior. Senate Journal. First Session, Fiftieth Congress.
From the Department.

Department of State, U. S. Report from the Consuls, July and August, 1888.
From the Department.

Department of State, U. S. Maps showing the Location of the Diplomatic and Consular Offices of the United States.
From the Department of State.

District of Columbia. Annual Reports of the Health Officer. 1882 to 1885.
From the Health Office.

Dubois, R. G. Manual of Patent Law. From the Author.

Dulles, C. W. Report on Hydrophobia. From the Author.

Engineers' Society of Pennsylvania. Meeting October 16, 1888.
From the Society.

Fondation Teyler. Catalogue de la Bibliothèque. Septième et huitième Livraison. From the Conservator of the Library.

Geological Survey of Arkansas. First Annual Report.
From the State Geologist.

Geological Survey of New Jersey. Final Report of the State Geologist. Vol. 1. From Prof. G. H. Cook.

Greeley, A. W. International Polar Expedition. Report on the Proceedings of the United Expedition. Vol. 1. From the Author.

Hamilton, Hugh. Chemical Factor in Disease.
Chemical Philosophy in Remedy. From the Author.

Harvard College Observatory. Annals. No. 6. Vol. 18.
From the Observatory.

Hydrographic Office. Pilot Chart North Atlantic Ocean. December, 1888.
From the Office.

Indiana. Twentieth and Twenty-third Annual Reports of the Superintendent of Public Instruction. From the Superintendent.

India. Meteorological Observations recorded at six stations in India, May to July, 1888. From the Meteorological Department.

Institution of Naval Architects. Transactions, Vol. 29, 1888.
From the Institution.

Kansas State Board of Agriculture. Report for August and September, 1888.
From the Board.

Kohlbusch, H. Illustrated Price List of Balances and Weights of Precision.
From Mr. H. Kohlbusch.

LeVan, W. B. Is Engineering on the Decline? From the Author.

The Loyal Girl of Winchester. From the Birchard Library.

Maternity Hospital. Fifteenth Annual Report.
From Mr. S. H. Needles.

Meteorological Council, London. Contributions to the Knowledge of the Meteorology of the Arctic Regions. Part 5.
Hourly Readings. Part 4. 1888. From the Council.

Michigan State Board of Health. Reprint, No. 290. From the Board.

Musée Teyler. Archives. Vol. 3. Serie 2. Second Partie.
From the Conservator of the Library.

Nelson, W. Aperçu de quelques difficultés à vaincre dans le construction du Canal de Panama. From Prof. Arthur Beardsley.

New Jersey. Tenth Annual Report of the Bureau of Statistics for 1887.
From the Chief of Bureau.

North Carolina Agricultural Experiment Station. Annual Report for 1886.
From the Board of Agriculture.

Oliver, Chas. A. Double Chorio-Retinitis with Partial Degeneration of the Optic Nerve. From the Author.

Otto Gas Engine. Instructions for Setting Up and Using.
From Mr. S. H. Needles.

Patent Office, British. Specifications of Inventions. Vols. 17 to 41 and 43.
1887. Name Index. August, 1888.
Subject Index. September, 1888. From the Office.

Patent Office, U. S. Specifications and Drawings. August, 1887, to December, 1887. From the Office.

Pennsylvania State College. Report for the year 1887. Part 2.
From the College.

Philip, George, & Son. A Classified and Descriptive Catalogue of Scientific and Technical Books. From the Publishers.

Public Documents, U. S. House Miscellaneous Documents. Vol. 13. Part 21. Second Session, Forty-seventh Congress.
From the Department of the Interior.

Public Free Libraries of the City of Manchester. Thirty-sixth Annual Report.
From the City Council.

Rogers, John. Illustrated Catalogue of Groups of Statuary.
From Mr. John Rogers.

Rome Mechanical Association. Constitution, etc. From the Association.

San Francisco Free Public Library. Tenth Annual Report of the Board of Trustees. From the Librarian.

Smithsonian Institution. Miscellaneous Collection. Nos. 666 and 667.
From the Institution.

Sprague Electric Railway and Motor Company. Publications Nos. 1, 2[a], 4[a], 5, 6[a], 7, 9, 10. Also, chart showing route of Richmond Union Passenger Railway, and four miscellaneous circulars. From the Company.

Storr's School Agricultural Experiment Station. Bulletin No. 2.
From the Station.

Sturtevant, B. F. Ventilation and Heating. From the Author.

Suffolk Trust and Investment Company. Announcement, etc.
From the Company.

Supervising Inspector-General of Steam Vessels. Annual Report ending June 30, 1888. From the Inspector-General.

Supreme Court of the United States. United States of America *vs.* the American Bell Telephone Company. Oral argument of Mr. Dickerson and Mr. Storrow. From Mr. J. J. Storrow.

Treasury, U. S. Annual Report of the Secretary for 1888.
From the Secretary.

Tucker, Willis G. Report to State Board of Health, New York.
Introductory address to the Eighth Lecture Course at the Albany Medical College. From the Author.

U. S. Naval Observatory. Report of the Superintendent for 1888.
From the Observatory.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, December 19, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, December 19, 1888.

Mr. JOSEPH M. WILSON, President, in the Chair.

Present, 120 members and fifteen visitors.

Additions to membership since last report, fifty-eight.

The Special Committee, appointed to devise and execute plans for increasing the membership, made an oral report of progress through its acting chairman, Prof. H. W. SPANGLER. The report was discussed by Messrs. G. M. ELDRIDGE, S. LLOYD WIEGAND, THOS. SHAW and others. The report was accepted and the committee was continued.

The following nominations for officers, managers, and members of the Committee on Science and the Arts were made viz.:

For *President* (to serve one year), ... JOSEPH M. WILSON.
For *Vice-President* (to serve three years), . . FREDERICK GRAFF.
For *Secretary* (to serve one year), ... WILLIAM H. WAHL.
For *Treasurer* (to serve one year), ... SAMUEL SARTAIN.
For *Auditor* (to serve three years), . . . WILLIAM A. CHEYNEY.

For *Managers* (to serve three years, eight to be elected):

GEORGE V. CRESSON,	JOHN LUCAS,
PERSIFOR FRAZER,	SAMUEL P. SADTLER,
EDWIN J. HOUSTON,	WM. H. THORNE,
ENOCH LEWIS,	JOHN J. WEAVER.

For *Members of the Committee on Science and the Arts* (to serve three years, fifteen to be elected):

L. L. CHENEY,	SAMUEL R. MARSHALL,	CHAS. E. RONALDSON,
L. D'AURIA,	WM. MCDEVITT,	SAMUEL SARTAIN,
J. L. GILL, JR.,	J. R. MCFETRIDGE,	CHAS. A. RUTTER,
F. LECLERE,	A. E. OUTERBRIDGE, JR.,	S. LLOYD WIEGAND,
W. B. LE VAN,	GEO. H. PERKINS,	CARL HERING.

Mr. THOMAS SHAW then gave a description of his Mine Inspectors' Instrument for the detection of dangerous gases in the air, illustrating his remarks by an exhibition of the operation of the apparatus, showing the capability of the instrument to detect the presence of such gases in the air to the fraction of a per cent.

Mr. SHAW's remarks will be prepared for publication.

Dr. ROBERT GRIMSHAW, of New York, read a paper on "The Industrial Uses of Cotton-Seed Oil," illustrating the same by the exhibition of a number of samples of products derived from the cotton seed. Referred for publication.

The President gave a description of a projected new building for the use of the INSTITUTE, from plans prepared by himself. The elevation and floor plans of the building were shown with the aid of the lantern.

Mr. FRED. E. IVES showed with the lantern a series of photographs of lightning flashes, sent to the INSTITUTE for exhibition by Mr. W. J. JENKS, of New York. The pictures were quite characteristic and were highly appreciated.

The following gentlemen were named by the President to serve as tellers at the forthcoming election, viz: Messrs. W. B. COOPER, C. J. HEXAMER, GEO. M. SANDGRAN, EDW. F. MOODY, W. J. JENNINGS, W. L. DUBOIS, and SAM'L H. NEEDLES.

Adjourned. H. L. HEYL, *Secretary pro tem.*

JOURNAL

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FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVII. FEBRUARY, 1889. NO. 2.

THE NICARAGUA CANAL.

By COMMANDER H. C. TAYLOR, U. S. Navy.

[*A paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *Wednesday, October 15, 1888.*]

(*Continued from Vol. cxxvii, page 47.*)

JOS. M. WILSON, President, in the Chair.

Concerning the traffic which will use the canal it may be divided into the following classes:

	Tons.
(1) Trade across the Isthmus, ...	1,217,685
(2) Trade between Atlantic and Pacific ports of United States, ...	145,713
(3) Trade between Atlantic ports of United States and foreign countries west of Cape Horn, ...	752,585
(4) Trade between Pacific ports of the United States and foreign countries east of Cape Horn, ...	879,844
(5) Trade around Cape Horn of European countries, . .	1,471,399
(6) Trade of British Columbia with Europe, ...	39,818
Total tonnage, ...	4,507,044

Our Pacific ports are now 13,000 and 14,000 miles away from us by way of Cape Horn. The distances by the canal will be 4,500 to 5,500 miles, and here again we shall gain a great stride upon Europe, and be the nearer to San Francisco by 2,500 miles, instead of being that much further away as we are now. The natural growth and development of these Pacific states and territories will soon furnish thousands of tons of traffic for the canal, for the hundreds that exist under the present conditions. San Francisco owns more ships and a greater tonnage to-day than at any previous time. Portland, Ore., with 40,000 inhabitants, last year handled 12,500,000 pounds of wool and 1,500,000 pounds of hops. Her domestic exports amounted to $9,000,000, and her foreign exports to $5,000,000. Her merchants moved 238,000 tons of wheat and flour, and her grain fleet numbered seventy-three vessels, registering 93,320 tons. The total foreign and coastwise exports from the Puget Sound collection district, last year, amounted to nearly $9,000,000. The salmon canneries of the Northwest coast shipped 1,500,000 cases. The acreage and product of the wheat fields of Eastern Oregon and Eastern Washington have doubled within ten years, and there is enough vacant wheat lands to permit the same phenomenon within the next decade.

The lumber trade of Oregon and Washington presents the most notable development of any line of commerce during the past year. In 1886, the total shipment was 6,000,000 feet. In 1887, it averaged 4,000,000 feet per month, or eight times the total of 1886. There are said to be 20,000 square miles of yellow and red fir alone in Washington, generally known in trade as "Oregon pine," and the trees of these forests reach twelve feet in diameter and 300 feet in height. The timber field of Oregon is a quarter of the superficial area of the state, or 25,000 square miles. The wheat, lumber, fish, wool, furs and other commodities of the Pacific Northwest will be provided to commerce in increasing quantities, and with greater profit to the producers, when cheap water transportation is at hand to convey them promptly to the world's markets.

The trade between Australasia and our Atlantic ports

has quadrupled since 1865, though it is still trifling in comparison with the total foreign commerce of those colonies; but it has grown to what it is without encouragement, and in spite of obstacles and disadvantages, and slight favoring circumstances might open up for us large possibilities in our relations with young English-speaking peoples whose foreign commerce already exceeds $500,000,000 per year. The total tonnage entered and cleared at New Zealand ports in 1885, exclusive of coasters, was 1,032,700, of which a considerable part was by sail with Europe. The distance from Liverpool to Auckland is 500 miles less by Nicaragua than by any other route, and 2,524 miles less than by the Cape of Good Hope. It might very well happen that a part, at least, of this European trade with New Zealand will choose the Nicaragua route, not so much for the distance saved over Cape Horn as for the more favorable weather, winds and currents to be met with in the latitude of the canal. Sailing vessels between Europe and Japan would, by way of Nicaragua, save at least 3,000 miles over other routes.

The stimulus which our domestic and near-by foreign commerce will receive from the safe and sure progress of an inter-oceanic canal towards completion, the natural increase, in six years, of all the classes of trade within the zone of attraction of the canal, and the fair probability of additions from the European traffic by sail with Japan, New Zealand, Fiji and the South Pacific groups, should render it safe to predict a total tonnage of six to six and a half millions for the Nicaragua Canal in 1894. If the cost of constructing the canal should prove to be double the estimate of the engineers, the financial adventure would still be safe and profitable. The commerce which exists to-day assures so much. Half of that commerce is our own. It is wonderful that it should have maintained itself so well in view of the disadvantages under which it has labored.

The greatest traffic of the Suez Canal in 1885 was 8,985,411 tons, in 3,624 vessels. Its present charges are nine francs per ton. While the tonnage and consequently the receipts fell off slightly in the following years, the latest returns show recovery from this slight relapse, and it is safe

to consider 9,000,000 as the present annual tonnage. It must be remembered that this canal opens into the Red Sea, which has always been impossible to sailing ships, on account of the calms. Situated as it is, the Nicaragua Canal route offers every facility for the passage to and departure from the termini of the canal of sailing vessels, for the trade winds are constant for ten months in the year, while for the other two a breeze blows in some direction, generally southwest, giving the vessels dependent on their sails, a constant opportunity to keep themselves under control.

A large portion of the traffic on the Suez Canal is by tramp or freight steamers, to whom economy in coal is of the first importance. Hence, these vessels, though they may return by Suez, will be undoubtedly glad to avail themselves of the favoring trades from Europe to Nicaragua, and again from Nicaragua to the Indies, or China and Japan and Australia.

It is safe, therefore, to conclude that a portion at least of the tonnage passing through Suez will find its way to Nicaragua.

Such then are the natural advantages and the general prospects of this enterprise. Let us see what the present company has done to avail itself of nature's favors.

The company has obtained from Nicaragua and Costa Rica concessions of great value. These have been ratified after due consideration by the Congresses of those Republics. The concessions bestow all privileges for this canal, and a railroad and telegraph along its route, as well as land grants amounting to about a million and a quarter acres, most of which is on the canal line. The company has for nearly a year kept a force of 200 men at work in Nicaragua, who have completed the most elaborate and detailed surveys of the location, and have acquired the most intimate acquaintance with the work before it.

Borings along the line of the canal have now been continued for ten months, and the cube to be extracted is intimately known, both in kind and quantity. In addition to this the company has presented the enterprise to the

notice of engineers, business men and capitalists of this country and Europe, in a thorough and impartial manner. It has blinked at nothing, has extenuated or concealed no defect or difficulty. The enterprise is now before the world, depending on its naked merits for approval. In carrying on these surveys and other works, the company has shown its sincerity by expending about $400,000, and this in addition to millions of dollars worth of work done by the United States Government on the same ground in the last twenty years.

The canal can be built and equipped for $60,000,000, but we must organize the final company liberally, and not cramp the enterprise, if unforeseen wars or other complications should intervene to increase its cost. We must be ready to use $100,000,000, if necessary. The traffic ready to use the canal as soon as opened, will give a net revenue of from $12,000,000 to $15,000,000 annually. The final work of the preliminary company is, therefore, to organize the Maritime Canal Company of Nicaragua and Costa Rica, with a capital of $100,000,000. A charter from the United States, though not indispensable, is undoubtedly beneficial, and an act of incorporation was introduced in Congress during the present session. It passed the Senate in February last, and will, it is believed, pass the House of Representatives in December next.

This great enterprise will have results far-reaching and permanent. The commercial world, which has been moving westward since the dawn of history, will be brought by this canal to Philadelphia, New York and New Orleans. The whole circulation in the veins and arteries of trade will be reversed in its direction.

It is a great satisfaction to me to be the humble agent selected to lay this project before so distinguished a society as the FRANKLIN INSTITUTE. I cannot doubt, had Benjamin Franklin lived in these days, that he would have been found in the fore-front of this enterprise, so fraught as it is with profit to our own commerce and industries, and so beneficial to all the dwellers upon earth.

APPENDIX.

[From *Engineering News*, of June 2, 1888.]

THE PROFILE.*

This profile was prepared for the Panama Canal Company, and printed during the current year, for the purpose of showing the work necessary to complete a lock canal. It was afterwards attempted to suppress it, as already noted. It shows, in a very striking manner, the amount of work done upon the Panama Canal during the seven years that it has been under construction, and gives an approximate idea of the amount necessary to complete the canal at sea level; a much more correct idea than it has been possible to form heretofore.

The profile should be considered in the light of M. de Lesseps' repeated declarations that the lock system is only a temporary expedient, and that the company is bound to complete the canal to the sea level, according to its original prospectus. It should also be borne in mind that there is no adequate water supply for the upper lock, 150 feet above the bed of the lowest level; that the problem of controlling the waters of the Chagres River is still unsolved, and that the other elements of doubt and difficulty concerning the lock canal are, if not as many and as great as those which surround the sea-level project, yet very many and very great.

The profile is from the copy referred to by M. Rondeleux in the speech from which we make an extract above.

The first announcement made by the Panama Company of the cube that would remain to be extracted under the lock plan was 40,000,000 cubic metres. In reporting the work done in February, the *Bulletin du Canal Interocéanique*, of May 2d, said: "There remains to extract 32,132,244 cubic metres."

A careful calculation, by scale, of the amount of excavation for the lock canal, as shown on the profile, between kilometres 18 and 67·300, conceding the completion of the two ends (though they are not complete by any means), and taking a slope of one and one-half to one throughout (which cannot be maintained in the higher parts), gives a total of 37,250,627 cubic yards.

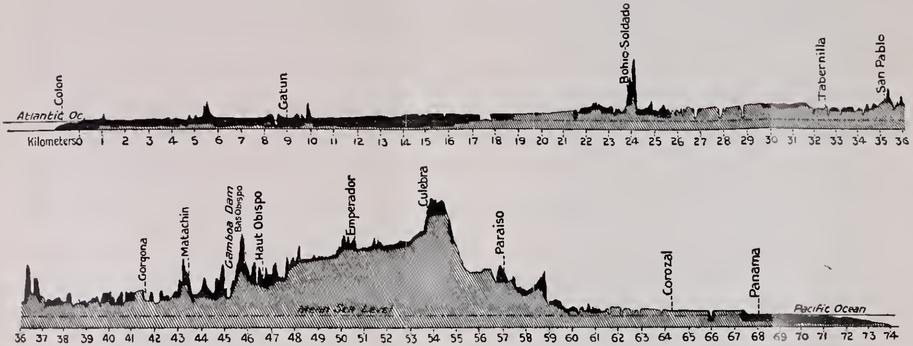
This aggregate amounts to 34,081,086 cubic metres, and takes no account of the work yet to be done in Panama Bay, or in the coral rock between kilometres 67 and 74, and without the channels for the deflection of the Chagres, the Rio Grande and the Obispo, amounting certainly to several millions of cubic metres.

The excavations for the locks will also be considerable in quantity, and it will be strange if they are not likewise of a difficult and tedious nature, since the locks are located in rock. It therefore appears far within the proabilities to place the total excavation remaining to be accomplished for the canal, with ten locks, at 50,000,000 cubic metres. If the upper locks be abandoned, as contemplated by the terms of the Eiffel contract, it will add largely to the cube and the difficulty.

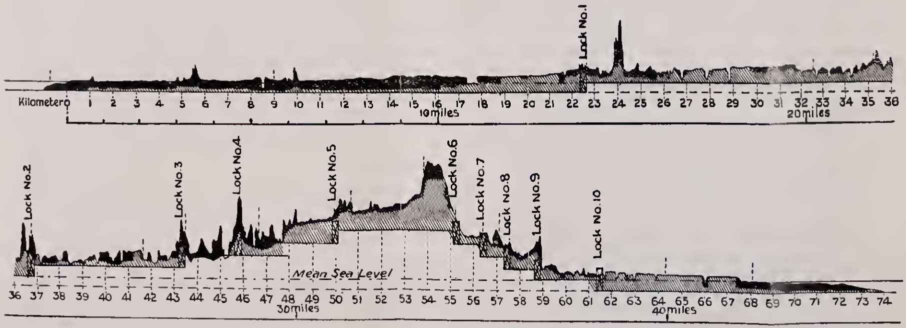
* For the use of this illustration we are indebted to *Engineering News*. (W.)

PROGRESS PROFILE OF THE PANAMA CANAL.

Showing the amount of work done towards building the canal, up to January 1, 1888.



[This profile exhibits the state of the work as a sea-level canal—when this plan was abandoned.]



[This profile was issued by the Panama Canal Company in January, 1888, primarily to show the lock system, and the small remaining amount of work.

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Now the company's rate of excavation, even with the help of the large figures from the Colon-Gatun section, has not averaged 1,000,000 cubic metres per month, the past two years through. At the best rate of progress, therefore, and with the most liberal allowances, there is work enough to consume four years, and that would involve the disbursement of something like $80,000,000 for interest and sinking fund of the debt and expenses of administration, without counting a dollar for work or material on the canal itself.

Though the work accomplished thus far has been the easiest that the line presents, still, more than one contractor has succumbed before the difficulties of the Culebra. Some of the richest and most experienced firms of Europe have declared the tasks of that portion of the line beyond their power to accomplish, and have abandoned their contracts. The laborers are not more numerous nor more efficient than they were when Señor Tanco Armero declared that the results of their work convinced him that there had never been more than 5,000 men employed, though the company claimed to have 15,000.

Again, the water for the supply of the lock system, so far as is known, is to be furnished from the Chagres River. In the dry season the flow of the Chagres is at the rate of ten cubic metres per second, of the Obispo one cubic metre, and of the Rio Grande 0·4 cubic metre. The three streams would therefore supply some 259,977,600 gallons per day. The capacity of each of the locks is 40,000 cubic metres, and each vessel crossing the summit level will require the two locks to be emptied once, using something like 80,000 cubic metres of water. The Panama Company claims a tonnage of 10,000,000 per year, or 28,000 tons per day, representing twenty vessels of 1,400 tons each, although this seems to us a most exaggerated estimate. The water required for their transit would be 322,400,000 gallons per day. The evaporation and filtration, estimated at one per cent. per day, would entail a loss of something like 47,300,000 gallons, making the daily requirement amount to 369,700,000 gallons. The supply is 259,977,600, and the shortage on this basis 109,765,260 gallons.

We should hardly expect from this computation that there would really be any shortage of water supply, since we have no belief that the traffic will reach 10,000,000 tons, or anything approaching it, for a long period of years, but it seems to be admitted that pumping will be necessary, and it seems to be proposed to provide for it. Therefore, we apprehend that this water supply estimate is really too liberal.

APPENDIX.—Tables covering twelve months from July 1886, to June, 1887, inclusive.

RIVAS—JULY, 1886. LAT. 11° 26′ N.; LONG., 85° 49′ W. 7 A.M., WASHINGTON TIME; 6·17 A.M., LOCAL TIME. BAR.—150 FEET ABOVE SEA LEVEL.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·90	77	80	NE	0	. . .	Clear
2	·90	77	80	SE	1	1·9	Cloudy
3	·90	75	82	NW	0	2·8	"
4	·92	78	80	N	1	. . .	Clear
5	·90	77	80	NE	0	. . .	"
6	·90	75	82	N	0	4·7	Cloudy
7	·90	74	82	SE	0	1·1	"
8	·90	75	82	"	0	. . .	Clear
9	·92	75	82	"	1	3·	Cloudy
10	·90	73	82	"	1	2·2	Clear
11	·90	75	82	"	0	. . .	"
12	·90	75	80	NE	0	. . .	"
13	·90	77	80	E	1	. . .	"
14	·90	74	80	SW	0	1·4	Cloudy
15	·90	75	82	"	2	6·	"
16	·92	74	82	"	1	3·3	"
17	·90	73	82	"	0	·2	Clear
18	·92	76	82	NE	1	. . .	"
19	·92	75	80	SE	0	. . .	"
20	·90	75	80	"	0	. . .	"
21	·90	77	80	NE	1	. . .	"
22	·90	77	82	"	0	1·7	Cloudy
23	·90	76	80	"	0	2·2	"
24	·90	77	80	E	0	. . .	Clear
25	·90	77	80	"	0	. . .	"
26	·90	76	80	"	1	·5	Cloudy
27	·90	76	80	N	1	·4	"
28	·90	77	80	E	1	·0	Clear
29	·90	77	80	S	2	·1	"
30	·90	73	82	SE	0	2·1	"
31	·90	73	82	E	0	4·6	"
			80·9			cm. 38·2 inches. = 15·09	

AUGUST, 1886.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·90	73	80	E	1	. . .	Clear
2	·90	75	80	NE	0	·6	"
3	·90	76	82	"	1	·5	Cloudy
4	·90	76	80	N	0	·4	Clear
5	·90	75	82	"	0	4·6	Cloudy
6	·90	75	82	"	1	·4	"
7	·91	75	82	"	1	1·8	"
8	·92	74	82	SE	1	1·1	"
9	·90	74	82	"	0	3·4	"
10	·90	74	82	"	1	4·5	"
11	·90	76	82	E	0	·6	Clear
12	·90	77	80	"	1	·1	"
13	·90	75	80	N	0	·2	"
14	·90	74	80	W	1	·6	"
15	·90	74	82	NE	1	1·4	Cloudy
16	·90	75	82	SE	1	1·9	"
17	·90	75	80	SW	0	·4	"
18	·90	74	80	W	1	·5	"
19	·90	73	82	"	1	·6	"
20	·90	74	82	SW	0	5·1	Clear
21	·90	74	80	SE	1	. . .	"
22	·90	76	82	SW	0	·4	Cloudy
23	·90	74	82	"	0	4·9	"
24	·92	74	80	S	1	. . .	Clear
25	·90	73	82	SW	0	2·5	Cloudy
26	·90	74	82	E	0	2·5	Clear
27	·90	74	82	SE	0	. . .	Cloudy
28	·90	74	82	"	0	2·6	"
29	·90	74	82	"	0	1·	"
30	·90	75	82	S	1	1·1	"
31	·90	74	82	NE	0	·3½	"
			87·3			cm. 44·05 inches. = 17·40	

SEPTEMBER, 1886.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·93	74	80	S	0	. . .	Cloudy*
2	·92	78	82	NE	1	. . .	Fair
3	·92	72	82	NW	1	. . .	Cloudy
4	·92	74	80	"	1	. . .	Fair
5	·90	76	78	NE	1	. . .	"
6	·90	75	78	SW	0	1·30	"
7	·91	74	78	S	0	·74	"
8	·90	75	80	SE	0	·18	Cloudy*
9	·90	74	81	E	0	·55	Fair*
10	·90	74	82	SE	0	·74	Cloudy
11	·92	77	80	E	1	·11	"
12	·92	77	80	"	1	. . .	Cloudy†
13	·90	74	81	SE	1	·35	"
14	·93	73	82	SW	2	1·70	"
15	·93	73	82	SE	0	1·10	"
16	·93	73·5	82	"	0	2·24	"
17	·91	73	83	NW	1	2·26	"
18	·91	74	82	"	1	. . .	"
19	·92	74·5	80	W	1	·02	Fair
20	·93	74·5	80	NW	0	. . .	Cloudy
21	·89	76	83	"	0	. . .	"
22	·89	76	81	"	1	·12	"
23	·92	73·5	82	S	0	·67	Clear
24	·91	76	80	SW	1	·55	Fair‡
25	·93	73	81	NW	0	·52	"
26	·92	74·5	82	W	0	·90	Cloudy
27	·90	76	81	SE	0	. . .	Cloudy§
28	·89	72	82	NW	0	·95	Clear
29	·92	75	82	E	0	·25	Fair
30	·94	75	83	SW	0	·05	Cloudy
			81			cm. 15·30 inches. = 6·04	

OCTOBER, 1886.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·93	74	80	SW	0	. . .	Fair
2	·92	73·5	81	SE	0	·27	Clear
3	·93	74	83	NW	0	1·14	Fair
4	·90	75	82	SW	0	·40	Cloudy
5	·94	73	80	NW	0	·08	"
6	·90	74	82	"	0	1·37	"
7	·92	75·5	82	"	2	·63	"
8	·94	76	82	W	2	1·50	"
9	·92	74·5	80	S	1	·80	Fair
10	·93	75	82	"	1	·02	"
11	·93	75	80	SW	1	. . .	Cloudy
12	·95	73·5	82	"	0	·35	"
13	·95	75	80	"	0	·04	Clear
14	·92	76·5	80	NE	0	·04	Cloudy
15	·93	76	81	"	0	·77	"
16	·94	75	78	"	1	·04	Clear
17	·92	76	80	"	1	. . .	"
18	·92	75	80	"	1	. . .	Cloudy
19	·90	72·5	81	"	1	·13	Fair
20	·90	72·5	80	"	0	·31	Clear
21	·90	72·5	78	"	0	·0	"
22	·90	72·5	77	NW	1	·10	Cloudy
23	·90	74	78	"	0	. . .	Clear
24	·92	74	78	"	0	·5	"
25	·93	71	77	E	1	·14	"
26	·93	75	79	"	0	. . .	"
27	·02	76	78	"	0	. . .	"
28	·88	75	76	"	0	. .	Cloudy
29	·90	76	80	"	0	·13	"
30	·92	76	77	"	1	. . .	"
31	·90	76	77	"	0	·13	Fair
			79·7			cm 10·85 inches. = 4·28	

* Smoky.

† Column of smoke from volcano near by. Rumbling from same.

‡ Thunder-shower.

§ Heavy thunder-shower S.E.

NOVEMBER, 1886.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·92	77	77	E	1	. . .	Cloudy
2	·90	74	80	NW	1	·27	Clear
3	·92	76	80	E	0	·35	Fair
4	·95	76	78	"	0	. . .	"
5	·93	76	79	"	1	·76	Cloudy
6	·90	75	76	NE	2	·08	Clear
7	·90	73	76	E	0	. . .	"
8	·92	75	75	NE	2	. . .	"
9	·92	74	76	"	1	·02	"
10	·92	77	76	"	2	. . .	Fair
11	·92	75	77	"	1	. . .	Clear
12	·90	76	79	"	0	. . .	Cloudy
13	·90	75	82	"	0	·07	"
14	·93	76	80	"	0	·02	"
15	·92	77	79	E	1	·04	Fair
16	·92	77	78	"	1	·86	"
17	·90	77	79	NE	1	·04	Cloudy
18	·91	76½	78	"	2	·06	Fair
19	·94	77	78	"	2	·19	Cloudy
20	·92	76	78	E	2	. . .	Fair
21	·90	76	76	"	2	·02	"
22	·92	76	78	NE	1	·02	"
23	·90	75½	80	"	1	·17	Clear
24	·90	74	80	"	0	·33	Fair
25	·91	73	79	SE	0	. . .	Clear
26	·93	75	80	E	1	·02	Cloudy
27	·92	74	78	NE	1	·43	"
28	·92	72	80	"	1	. . .	Clear
29	·92	74	77	"	1	. . .	"
30	·92	74	76	E	1	. . .	"
	29·916		78·1			cm. 3·75 inches. = 1·48	

DECEMBER, 1886.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·92	74	77	NE	1	. . .	Fair
2	·93	74	78	"	2	. . .	Clear
3	·92	74	78	"	2	. . .	"
4	·01	74	77	"	2	. . .	"
5	·92	74	78	"	1	. . .	"
6	·92	75	74	"	2	. . .	"
7	·92	71·5	70	"	3	. . .	"
8	·92	73	73	E	2	. . .	"
9	·92	74	77	ENE	1	. . .	Cloudy
10	·92	74	78	"	1	. . .	Clear
11	·92	75	78	NE	2	. . .	Fair
12	·92	77	77	ENE	1	. . .	"
13	·92	76	77	NE	2	. . .	"
14	·92	75	78	"	3	. . .	"
15	·92	73	78	"	0	. . .	Cloudy
16	·92	73	78	"	3	. . .	Clear
17	·92	74	74	"	3	. . .	"
18	·92	75	79	"	2	. . .	"
19	·92	74	78	"	1	. . .	"
20	·92	74	78	"	1	. . .	"
21	·92	74	77	"	2	·47	"
22	·94	76	78	"	1	. . .	"
23	·93	76	77	"	2	. . .	"
24	·92	75	78	"	1	. . .	"
25	·92	74	77	"	1	. . .	"
26	·93	74	78	"	1	. . .	"
27	·92	75	78	"	1	. . .	"
28	·92	75	79	"	1	. . .	"
29	·93	74	79	"	1	. . .	"
30	·92	74	77	"	1	. . .	"
31	·90	72	80	"	0	·02	"
	29·921		77·1			cm. ·49 inches. = ·19	"

JANUARY, 1887.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·92	70	80	E	0	. . .	Clear
2	·92	75	79	NE	3	. . .	"
3	·92	72	70	"	3	. . .	"
4	·93	72·5	72	E	2	. . .	Cloudy
5	·92	71	75	ENE	2	. . .	Fair
6	·92	73	70	E	1	. . .	Cloudy
7	·92	74	79	NE	2	. . .	Fair
8	·91	75	79	E	1	. . .	Cloudy
9	·91	75	76	NE	2	. . .	Clear
10	·92	75	79	"	1	. . .	Fair
11	·93	77	78	"	2	. . .	Cloudy
12	·92	73	78	"	1	·50	"
13	·93	73	80	"	1	·10	Clear
14	·93	73·5	78	E	1	·02	Fair
15	·93	74	78	"	2	. . .	Clear
16	·93	74	78	NE	3	. . .	Cloudy
17	·93	73	79	E	1	·13	"
18	·95	73	74	"	2	. . .	Clear
19	·93	73	73	ENE	3	. . .	"
20	·93	73	80	"	3	. . .	"
21	·93	74 5	76	"	2	. . .	"
22	·92	74	78	"	3	·10	Cloudy
23	·92	74	78	E	2	. . .	Clear
24	·92	74·5	79	"	1	. . .	"
25	·92	73	77	"	2	·02	"
26	·92	73·5	79	ENE	3	. . .	"
27	·92	74	77	NE	3	. . .	"
28	·93	73·5	77	ENE	4	. . .	"
29	·93	73·6	81	NE	3	·03	Fair
30	·92	75 2	78	E	1	. . .	"
31	·92	74	78	NE	3	. . .	Clear
			77·1			cm. ·90 inches. = ·35	

FEBRUARY, 1887.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	29·92	75	78	E	3		Clear
2	·92	73	80	"	2	·33	Cloudy
3	·91	73·5	79	"	2	·15	Fair
4	·89	74	79	"	2	·08	"
5	·90	74	78	"	3	·05	Cloudy
6	·92	74	80	"	2	·08	"
7	·93	74	78	NE	2	. . .	Clear
8	·92	75	77	"	3	·08	"
9	·93	73	76	"	3	. . .	"
10	·93	74	75	"	3	. . .	Fair
11	·93	73	78	E	1	. . .	Clear
12	·90	74·5	78	"	4	. . .	"
13	·92	73	74	"	4	. . .	"
14	·93	74	76	"	3	. . .	"
15	·93	74	78	"	3	. . .	Cloudy
16	·92	74	80	ENE	2	·04	Clear
17	·92	73	78	"	1	. . .	Fair
18	·93	73	78	"	—	. . .	Clear
19	·92	74	78	E	1	. . .	"
20	·91	75	78	"	1	. . .	"
21	·92	74	78	"	1	. . .	Cloudy
22	·93	74	76	"	1	. . .	Fair
23	·93	73	79	"	1	. . .	"
24	·93	74	78	"	2	. . .	"
25	·92	76	76	"	2	. . .	"
26	·91	75	77	"	2	. . .	Clear
27	·92	74	78	"	2	. . .	"
28	·92	74	78	NE	3	. .	Cloudy
			77·6			cm .81 inches. = ·32	

MARCH, 1887.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
1	29·94	74	76	E	5	None.	Clear
2	·94	74	76	"	2		Fair
3	·93	74	77	"	3		Clear
4	·93	74	76	ENE	4		"
5	·93	73·5	77	E	3		"
6	·92	74	75	"	2		"
7	·93	73	78	"	1		"
8	·93	72·5	78	"	1		"
9	·93	73	78	ENE	1		"
10	·93	73	78	"	1		"
11	·93	73	78	"	2		"
12	·93	73·5	78	"	1		"
13	·93	74	76	E	1		"
14	·93	75	78	"	2		Cloudy
15	·93	74·5	75	E x N	3		Clear
16	·92	73	75	E	1		"
17	·92	74	75	ENE	1		"
18	·92	74	77	E	2		"
19	·92	73	75	ENE	2		"
20	·92	73	77	"	2		"
21	·92	73	77	E	1		"
22	·92	74	78	"	2		"
23	·92	75	78	"	1		"
24	·92	75	78	"	1		"
25	·92	75	78	"	1		"
26	·92	74	78	"	2		Fair
27	·92	74	78	"	3		Clear
28	·88	74	77	"	2		"
29	·90	74	78	"	1		"
30	·90	75	78	"	2		Cloudy
31	·90	75	78	"	2		Clear
		77·9					

APRIL, 1887.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-Four Hours.	State of Weather.
1	29·90	74·5	78	E	1	None.	Winds through January and February increased in force about 10 A M.
2	·90	74·8	78	"	2		
3	·93	75	78	"	2		
4	·92	75·2	79	ENE	3		
5	·94	75	78	"	2		
6	·93	75	78	E	2		
7	·92	76	78	"	3		
8	·93	76	78	ENE	2		
9	·92	76	78	E	1		
10	·92	76	77	"	2		
11	·90	76	77	"	1		
12	·93	77	77	ENE	1		
13	·92	77	78	E x S	1		
14	·93	77	80	E	1		
15	·90	77·5	78	"	1		
16	·91	77·5	78	"	1		
17	·90	77	79	"	1		
18	·89	77·5	79	"	1		
19	·89	77	77	ENE	1		
20	·90	78	78	E	1		
21	·90	78	78	"	1		
22	·90	77	78	ENE	2		
23	·90	76·8	77	E	2		
24	·89	78	78	"	1		
25	·87	77	79	"	1		
26	·90	77	78	ENE	1		
27	·93	77	78	"	3		
28	·93	77	78	E	3		
29	. . .	77	76	NE	2		
30	. . .	76	78	E	1		
			77·9				

MAY, 1887.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
						cm.	
1	. . .	78	78	E	2	. . .	Clear
2	. . .	78	78	NE	2	. . .	"
3	. . .	76	77	"	1	. . .	"
4	. . .	76	78	E	2	. . .	"
5	. . .	78	78	"	2	. . .	"
6	29·92	78	78	NE	2	. . .	"
7	·93	78	80	E	1	. . .	Fair
8	·90	78	78	"	1	. . .	Cloudy
9	·92	78	79	N	1	. . .	"
10	·90	78	79	NE	1	. . .	"
11	·92	75	80	E	1	. . .	"
12	86	77	88	NE	1	. . .	Fair
13	·86	75	89	W	1	. . .	Clear
14	·88	79	82	NE	0	·02	Cloudy
15	·90	74	80	"	1	1·41	Fair
16	·92	76	80	W	1	1·31	Cloudy
17	·87	76	80	"	0	·27	"
18	·90	75	80	"	0	·67	Fair
19	·90	73	80	S	1	4·09	Cloudy
20	·93	73	80	"	1	·59	Fair
21	·97	74	80	W	1	·19	"
22	·98	75	80	"	0	·15	"
23	. . .	75	80	SE	1	·28	"
24	. . .	74	80	"	0	. . .	Cloudy
25	. . .	77	80	"	1	·04	"
26	. . .	78	79	E	1	. .	"
27	. . .	77	79	"	1	·15	"
28	. . .	75	79	SE	2	. . .	Fair
29	. . .	77	79	E	2	. . .	Cloudy
30	. . .	77	79	"	1	. . .	"
31	. . .	78	79	"	1	. . .	"
			79·9			cm. 9·17 inches. = 3·62	

JUNE, 1887.

Day.	Bar.	Dry Bulb.	Relative Humidity.	Wind. Direction.	Wind. Force.	Rainfall in Twenty-four Hours.	State of Weather.
1	None.	78	79	E	1	. . .	Fair
2		77	79	"	1	. .	Cloudy
3		78	79	"	0	·15	"
4		75	79	NE	1	. . .	Fair
5		77	80	W	0	. . .	Cloudy
6		78	80	E	1	·31	"
7		77	80	"	0	·78	"
8		76	80	N	0	. . .	"
9		75	80	E	1	. . .	Fair
10		76	80	"	1	·08	Cloudy
11		75	80	W	0	1·26	"
12		75	80	"	0	. . .	Fair
13		73	80	"	0	. . .	"
14		76	80	"	0	. . .	Cloudy
15		75	80	"	0	. . .	Clear
16		76	80	"	0	·43	"
17		74	81	"	0	·16	Cloudy
18		75	80	"	0	·13	Fair
19		76	80	"	0	·58	Cloudy
20		74	81	"	0	·50	"
21		75	80	"	1	·44	Clear
22		75	80	"	1	·08	Cloudy
23		74	80	"	1	·40	Fair
24		74	80	E	1	·16	Clear
25		74	81	SE	1	2·56	Cloudy
26		75	80	E	0	·16	Fair
27		77	80	SE	4	. . .	Clear
28		77	80	NE	1	. . .	"
29		77	80	"	1	. . .	"
30		77	80	E	0	. . .	Cloudy
			79·9			cm. 8·18 inches = 3·23	

Mean humidity for year, 73·9. Rainfall for year, 131 70 cm. = 52·00 inches.

In order to test the capacity of the canal as regards its facility for navigation, let us compare it with the Suez Canal, whose financial success is already well established. The Suez Canal is 100 miles long, with a continuous depth of twenty-six feet, and a uniform bottom width of seventy-two feet.*

The width of surface water varies from 190 to 330 feet, according to the slope required by the soil.

"The area of water prism ranges, therefore, between a minimum of 3,406 square feet and a maximum of 5,226 square feet. The minimum radius of curve is 2,000 feet. Its entire length is open to ships of all nationalities, provided their draught does not exceed 7·51 metres (24′ 7″).

"The maximum speed of all ships passing through the canal is fixed at ten kilometres (equal to $5\frac{1}{8}$ nautical miles or $6\frac{1}{10}$ statute miles) per hour. (From regulations for navigation of Suez Canal).

"Vexatious delays, due to grounding in rounding the sharp curves and in going in and out of the sidings to allow other vessels to pass and stoppages for the night, make the time of vessels in the canal range from forty to seventy hours.

"However, the average effective sailing speed, as given in the reports of the company, is five knots an hour. The passage has been made in fifteen hours by starting at break of day and getting through before dark."

At Suez the traffic has been seriously delayed by the dimensions of the canal and the inadequate number of turnouts.

In the present project not only have enlarged prisms been provided for, but large basins are proposed at the extremities of the locks. These basins, the enlargement of the canal at each end, with the lake, the river and the San Francisco Basin, will permit vessels to pass each other without delay at almost every point on the route.

In 21·0 miles or 72·9 per cent. of the canal in excavation, the prism is large enough for vessels in transit to pass each other, and of a minimum sectional area of 4,500 square feet.* The remaining distances in which large vessels cannot conveniently pass each other are so divided that the longer is only 4·73 miles in length and the shorter 3·07 miles. These short reaches of narrow canal are situated between basins, and can be traversed by any vessel in the same or less time than is estimated for the passage of a lock; consequently unless a double system of locks be constructed nothing will be gained by an enlargement of the prisms.

The possible detention in the transit, due to those narrow cuts, which should not in any case exceed forty-five minutes, would not justify the necessary increase of expense involved in an enlargement of the cross-section proposed. Both the bottom width and the depth of the proposed canal are larger than those of the Suez Canal.

"In the lake and in the largest portion of the San Juan River vessels can travel almost as fast as at sea. In some sections of the river, and possibly in the basin of the San Francisco, although the channel is at all points deep and

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* The sectional area of the North Sea and Baltic Canal, inaugurated June 3, 1887, is 3,934 square feet, and will permit the passing of ordinary ships at any point.

of considerable width, the speed may be somewhat checked by reason of the curves.

ESTIMATED TIME OF THROUGH TRANSIT BY STEAMERS.

	Hours.	*Minutes.*
28·89 miles of canal at five miles an hour, ...	5	46
20·28 miles in the San Francisco, Machado, Deseado and La Flor basins, at eight miles an hour, . . .	2	32
64 miles in the San Juan River at nine miles per hour,	7	6
56·50 miles in the lake at ten miles an hour, . . .	5	39
Time allowed for passing six locks at thirty minutes each, ...	3	
Allow for detention in narrow cuts, ...	1	30
	25	24

"The experience of the Suez Canal shows that the actual time of transit is more likely to fall under than to exceed the above estimate.

"The traffic of the canal is limited by the time required to pass a lock, and on the basis of thirty-five minutes (above estimated) and allowing but one vessel to each lockage, the number of vessels that can pass the canal in one day will be forty-eight, or in one year 17,520, which, at the average net tonnage of vessels passing the Suez Canal (2479·4 for 1885), will give, as the annual capacity of the canal, 43,422,088 tons. This is on the basis that the navigation will not be stopped during the night.

"With abundant water-power at the several locks and the dam, there is no reason why the whole canal should not be sufficiently illuminated by electric lights; and with beacons and range lights in the river and lake, vessels can travel at all times with perfect safety."

In preparing this paper, the writer has not hesitated to draw upon the writings of many gentlemen, as sources of information; as regards engineering features, he is indebted to United States Civil Engineers Menocal and Peary, and to Mr. J. C. Hueston of the Nicaraugua Canal office.

[At the close of Commander Taylor's remarks, the thanks of the meeting were tendered to him for his able and interesting presentation of this important subject.]

SPIRALLY WELDED STEEL TUBES.

BY J. C. BAYLES.

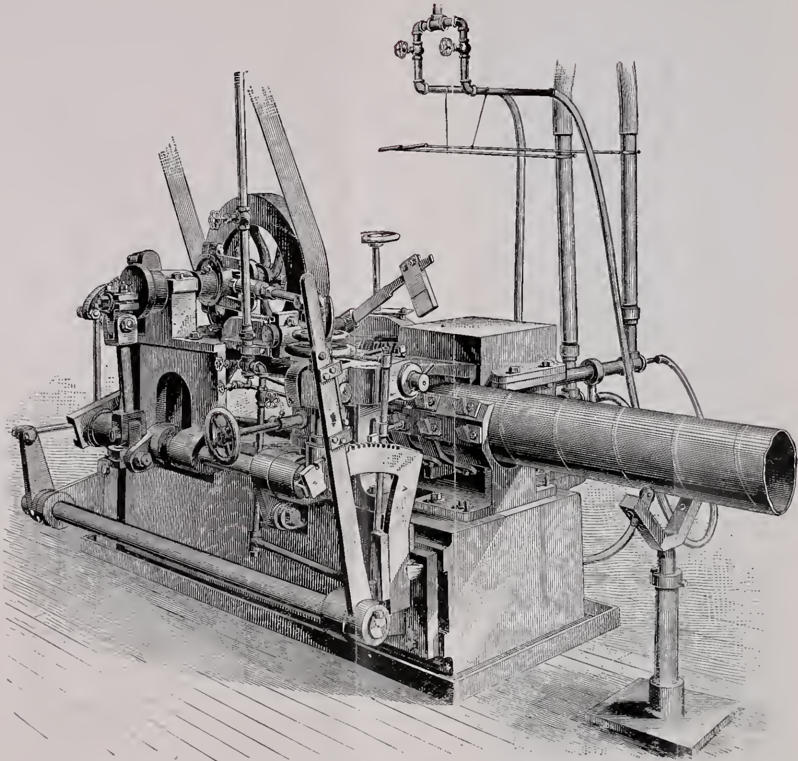
[*An abstract of remarks made at the meeting of the* INSTITUTE, *held Wednesday, January 16, 1889.*]

JOSEPH M. WILSON, President, in the Chair.

MR. BAYLES: — MR. PRESIDENT AND MEMBERS OF THE INSTITUTE:

The manufacture of light steel pressure pipes made from strips of metal wound laterally and hammer-welded, is an entirely new industry, employing means and producing results wholly unlike any before known in the arts.

In iron and steel pipe, it is desirable to use no more material than is needed to give the strength desired. This is true of all products, the progress of the arts tending steadily to a good constructive use of material, to secure a maximum of strength with a minimum of dead weight. As the rule, lap-welded tubes are enormously heavier than anything in the service to which they are subjected, warrants. They are made so for no other reason than that lighter stock than that employed in making them cannot be used. If the stock is heated in sheets, drawn from the furnaces at the welding temperature, shaped on a mandrel and welded, a considerable body of stock is needed to hold the heat during the shaping and welding processes. With thin sheets one of two things would happen: either the metal would chill instantly when drawn from the furnace, and refuse to weld; or, if hot enough, would collapse upon itself, defeating all efforts to shape and weld it. Light pipes would have been made by lap welding long ago had it been possible. As it is, they are much heavier than their strength calls for, the longitudinal weld being, as the rule, a line of weakness. In spirally welded pipes we have the material used to the very best advantage. The weld,



Machine for Making Spiral-Weld Tubes.

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instead of being a line of weakness, is a spiral reënforcement. A circumferential twisting strain is not created transversely to the weld, but longitudinally; or, to be more accurate, obliquely; and such pressure does not tend to open the seam, as in the case of a longitudinal weld, but to close it. The behavior of a spirally-welded pipe under pressure is illustrated by a very simple experiment. Roll a ribbon of paper into a spiral tube, as children make lamplighters, pinch one end tightly shut and blow in the other. It will be found that the first effect of internal pressure is to tighten the seams, and the paper may be burst before any air will leak out between the edges of the parts in contact. I have seen a defective spirally-welded pipe leak under twenty pounds pressure, become tight at fifty pounds, and remain tight up to 350 pounds per square inch. Under an internal bursting strain, the strength of a spirally-welded tube is found in the testing machine to be as great as the theoretical strength of the stock.

The process of manufacture is simple and inexpensive, but has entailed many and serious difficulties. These, however, have been overcome. Steel of suitable quality, *i. e.*, weldable, and having a tensile strength of 65,000 pounds per square inch, with about fifty per cent. reduction of area and fifteen to eighteen per cent. elongation, is rolled in grooves to the proper width, and as long as may be convenient. These strips are welded end to end in a machine built for the purpose, which works very well. As they are welded into long bands, the strips are rolled on large reels, which are passed to the pipe machines.

The pipe machine is shown in the accompanying illustration.

The essential features of the pipe machine are a guide-table for the skelp, adjustable to the desired angle; feed-rolls, to pass it forward with an intermittent progress, so that it shall advance when the former is raised and be at rest when it falls; a former, to curve the metal to the desired radius, also adjustable; a furnace, to heat the metal; a hammer, to weld it, and an anvil to support the pipe and receive the shocks of the hammer. No mandrel is used. The pipe in

the forming process is held in place by a pipe-mould, which is a cylindrical shell, within which the pipe rotates as the stock is fed in. The anvil is of considerable mass, steel-faced, and extends the entire width of the skelp. The hammer is light, and at normal speed strikes 350 blows per minute. The heating is done in a furnace so constructed as to heat both the edges to be united for the space of several inches ahead of the point at which the welding is effected. The upper skelp enters the furnace flat, and the lower skelp curved, having already been through the forming-jaws. The heat is imparted by one or two blow-pipes of water gas and air, discharging upon the metal through passages of suitable form in the refractory lining of the furnace. One gas-flame has been found sufficient, but two work better; and besides being more convenient to control, they heat the metal more rapidly and permit an accelerated feed. As very little gas is wasted, the greatest economy attends the most rapid production of pipe, irrespective of the quantity burned, which in any case is about thirty feet per foot of welded seam. The speed of production depends, as stated, upon the thickness of stock to be heated, and the relation of width of skelp to diameter. It averages a foot per minute to each machine, and it is probable this average can be raised considerably. The machines are so nearly automatic in operation that very little skilled labor is needed in running the plant. The operator has his gas, air and feed under control by convenient means, and varies their relations until he has them just as he wants them. He can see the edges as they emerge from the furnace, and about all the skill he needs is that which will enable him to judge by its color whether the iron is above, below or at the welding-heat. Unskilled labor prepares the stock and removes the finished product. The ends of the pipe are cut square by suitable machinery without reversing, and after testing and treating with asphalt, the pipe is ready for shipment. As may be supposed, all the difficulties of mechanical development have centred in the pipe machine. To make this satisfactory in operation has probably been no more serious task than is usually entailed in the effort to make old

mechanical motions perform new functions, but it has consumed a great deal of time and money.

The strengths attainable in light pipe, if the material is used to the best advantage, are quite surprising. A 6-inch pipe, made of No. 14 gauge iron of good average quality, showing under test 33,000 pounds elastic limit, and 50,000 pounds ultimate strength, has a proof strength of 913 pounds per square inch, and an ultimate strength of 1,383 pounds per square inch. A 12-inch pipe of the same stock has a proof strength of 456 pounds, and an ultimate strength of 691 pounds. If a good grade of soft steel is used instead of iron, the 6-inch pipe will carry 1,106 pounds pressure without deformation, and will not burst under 1,800 pounds; the 12-inch pipe can be tested to 475 pounds and will carry 900 pounds without fracture. This is very practical pipe. Using the same diameters and gauges of stock for comparison, we find that the 6-inch spirally-welded pipe weighs 5·2 pounds per foot against 18·77 pounds per foot for standard lap-welded pipe, and 28·28 pounds for medium cast-iron pipe; the 12-inch spirally-welded pipe weighs 10·46 pounds against 54·65 pounds for lap-welded and 77·36 for medium cast iron. I give below tables of strength for steel tubes.

Spirally-Welded Steel Tubes.

Proof strength of stock, 40,000 pounds per square inch.

Ultimate strength of stock, 65,000 pounds per square inch.

Diameter of Pipe.	Gauge.	Proof Strength Per Sq. In.	Ultimate Strength Per Sq. In.
4	18	980	1593
	16	1300	2113
	14	1660	2697
5	18	784	1274
	16	1040	1690
	14	1328	2158
6	18	653	1062
	16	866	1408
	14	1106	1798
8	18	490	796
	16	650	845
	14	830	1079
	12	1090	1771
	10	1340	2177
	8	1650	2681
10	18	392	637
	16	520	845
	14	664	1079
	12	872	1417
	10	1072	1742
	8	1320	2145
12	18	326	531
	16	433	704
	14	474	899
	12	727	1181
	10	893	1451
	8	1100	1788
14	18	280	455
	16	371	603
	14	474	771
	12	623	1012
	10	765	1244
	8	943	1532
16	18	245	398
	16	325	528
	14	415	674
	12	545	886
	10	670	1088
	8	825	1341
18	18	218	354
	16	289	469
	14	369	599
	12	484	787
	10	596	968
	8	733	1192
20	18	196	319
	16	260	422
	14	332	539
	12	436	709
	10	536	871
	8	660	1073
22	18	178	289
	16	236	384
	14	302	490
	12	396	644
	10	487	791
	8	600	975
24	18	163	265
	16	216	352
	14	277	449
	12	363	590
	10	446	726
	8	550	894

Owing to its superior advantages, we shall use steel exclusively in future. It is twenty-five per cent. stronger than good iron, works better and costs less per pound.

The advantages of spirally-welded tubes over any other form of pressure pipes, as regards economy of transportation and handling, are very marked, as will appear from the comparisons of the following table:

COMPARATIVE WEIGHTS OF PIPES, PER LINEAR FOOT, WITHOUT COUPLINGS OR HUBS.

	Spirally-Welded Steel or Iron.						Lap-Welded Iron.	Cast Iron.		
Diameter of Pipe.	No. 18.	No. 16.	No. 14.	No. 12.	No. 10.	No. 8.	Standard.	½ inch Thick.	⅝ inch Thick.	¾ inch Thick.
In.	*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*				
4	2·06	2 73					10·72	22·05	28·28	34·94
5	2 58	3·42					14·56	26 94	34 34	42 38
6	3·09	4·10	5·20				18·77	31·82	40·56	49·6
8	4 13	5·47	6·98				28·35	41·64	52 68	64·27
10	5·16	6·83	8·72	11·44	14·08		40·64	51·46	65 08	78·99
12	6·18	8·20	10·46	13·74	16·90	20·80	54·65	61·26	77·36	93·7
14	7·22	9·57	12·20	16·02	19·72	24·86		71 07	89·61	108 46
16	8·25	10·93	13·95	18·30	22·54	27·72		80·87	101 82	123·14
								⅝ inch Thick.	¾ inch Thick.	⅞ inch Thick.
18	9·28	12·30	15·69	20·69	25·35	31·19		114·1	137·84	161 9
20		13·66	17·44	22·28	28·16	34 66		126·33	152·53	179·02
22		15·03	19 18	25·27	30·98	38·12		138·6	167·24	196·46
24		16·40	20·92	27·48	33·80	41·60		150·85	181·92	213·28

The question of durability in service is one which naturally suggests itself when light steel or iron pipes are discussed. Experience on the Pacific Coast seems to have settled this question, as the cheap expedients adopted for water-conveyance during the days when hydraulic mining was most extensively conducted have been followed ever since in permanent engineering works. The best attainable data on this subject which I have found, are presented in a paper read by Hamilton Smith, Jr., before the British Iron and Steel Institute, and printed in vol. i. of the *Journal* for 1886. Much of the information contained in this paper is quite surprising, especially in the case of the two mains across Humbug Cañon. These pipes were laid in 1868.

They are of twenty-six inches diameter, 1,194 feet long, of common iron one-sixteenth inch in thickness, single riveted. During all this time they have been delivering water under 120 feet head, and Mr. Smith gives the maximum tensile strain in pounds on the metal per square inch as 11,500, Large as these figures look, they are simply the result of applying to the conditions given in Rankine's well-known formula for their cylindrical shells.

Riveted pipe in its best estate labors under the disadvantage of inherent structural weakness, and liability to rust between the overlapping edges and around the rivets. Pipes of this character on the Pacific Coast are very roughly tarred in position, and the coating is quite liable to be pulled off by the adobe clay in which most of them are laid; but they have a record of useful life since 1853, and many towns are supplied with water under considerable heads from pipes of this kind which have been more than twenty years in service. A welded pipe carefully coated with asphalt should, with fair treatment, have a record at least as good, and probably much better.

The coupling of light pressure pipes involves no difficulties, but it entails new methods. These are convenient and inexpensive, and make perfectly tight joints. The couplings are chiefly of cast iron, and their form depends upon the service in which the pipe is to be employed. Steam, water, petroleum, compressed air and gas, all present different problems in couplings, but no difficulties which have not already been fully met. The couplings are as practical as the pipe. The one generally preferred is the "trumpet flange." The pipe is slipped through the flange, and the projecting end is expanded and laid flat against the face of the flange. The ends of the pipes are thus brought in contact with the gaskets, making perfect joints under all circumstances.

Spirally-welded tubes are adapted for every use calling for pressure pipes. In the paper, before referred to, Mr. Hamilton Smith, Jr., after reciting American engineering experience with light iron tubes, concludes as follows:

"The query presents itself. Why should not wrought

iron or, still better, steel, be used for conduit pipes in preference to cast iron? If it answers the desired purpose in California, why should it not do so in other parts of the world? To one, like myself, who has for years been accustomed to the California practice, it seems as irrational to build a pipe of cast iron carrying water under considerable pressure, as it would be to build a suspension bridge with the supporting chains made of cast iron.

"Experience in the United States has shown that the practicable limit of size for cast-iron mains is a diameter of about four feet, even when the pressure is less than 100 pounds. It is evident that a pipe of wrought iron or mild steel can be safely made of almost any desired size, and this may be of much advantage if it be desired to conduct a large supply of water through pipes for city or other use. For instance, with an inclination of three feet per mile a single pipe eight and one-fourth feet in diameter will carry 280 cubic feet per second, while seven pipes, each four feet in diameter, would be required to transport the same quantity of water with the same inclination. The cost of the large pipe, made of steel or wrought iron, would be considerably less than one-half the cost of the seven small pipes made of cast iron.

"The ideal conduit for high pressures is a welded steel tube; such tubes could probably be subjected to a tensile strain of 25,000 pounds with perfect safety, and would be much preferable to riveted pipe, not only on account of superior strength, but also by reason of almost perfect interior smoothness. * * * The adaptation of a superior and cheap metal, such as mild steel for conduits, will permit the construction of hydraulic works in many parts of the world which now appear to be impracticable, owing to the cost of many of the methods still in use for the transportation of water."

Spirally-welded steel tubes meet all the conditions above described. The industry gives promise of rapid and even phenomenal development, as the cheapness and excellence of the product commands for it instant recognition as the most valuable of recent contributions to engineering materials.

SOME AMERICAN CONTRIBUTIONS TO METEOROLOGY.

By Prof. Wm. M. Davis, of Harvard College.

[*A Lecture delivered before the* Franklin Institute, *November 19, 1888.*]

The lecturer was introduced by Prof. Edwin J. Houston, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

If our object were to learn the science of meteorology in systematic order, the contributions made to it from our own or from any other single country would form an illogical subject for a lecture; but the fostering of scientific investigation has always been one of the objects of the Franklin Institute, and to this end it may be profitable to review the past as an encouragement to the future; to look over the great contributions that Americans have thus far made to meteorology and thus learn the responsibility for future work that rests upon us. The highly respectable position that we occupy in the history of this science should spur us on to new discoveries.

From the abundance of material, I shall have time to mention only the labors of seven of our meteorologists: Franklin, Redfield, Espy, Tracy, Ferrel, Coffin and Loomis; and in order to give some continuity to the lecture, I shall select chiefly certain suggestions and discoveries made by these eminent men in connection with the irregular disturbances in the atmosphere, known as storms. Many other matters, as well as the labors of Mitchell, Maury, Henry, Blodget, Abbe, and others, must be passed over.

We cannot do better than begin with mention of certain contributions made by the illustrious Franklin. Twenty years before he took his pre-eminent part in our Revolutionary history, he was a leader among the Colonists in several lines

of scientific research, in all of which he showed that keen and critical power which distinguishes the man of high ability. His demonstration of the identity of lightning and electricity is commonly known; it is an extraordinary thing, for since the old days of Jovian thunderbolts, lightning was regarded as outside the ordinary bounds of physical phenomena, and more in the nature of a special creative or rather destructive act. It was as early as 1747 that Franklin conceived the idea that lightning and electricity were identical, but no demonstration of their identity was made until 1752, when a French physicist undertook experiments on the line indicated by Franklin, and drew the electric fluid, as it was then commonly called, down from the clouds. In the same year, but a little later, Franklin performed his extraordinary experiment with a kite, on the outskirts of this city, one of the most daring experiments ever tried; indeed, it proved fatal to a Russian imitator within the year. The result was so decisive that no one has ever questioned it successfully.

Another suggestion from Franklin was that our northeast storms came from the southwest; and with this began the science of weather prediction. Franklin's first mention of this was in a letter to Jared Eliot, dated at Philadelphia, 16th July, 1747. He wrote: "We have frequently along the North American coast storms from the northeast, which blow violently sometimes three or four days. Of these I have had a very singular opinion for some years, viz: that, though the course of the wind is from northeast to southwest, yet the course of the storm is from southwest to northeast; the air is in violent motion in Virginia before it moves in Connecticut, and in Connecticut before it moves at Cape Sable, &c. My reason for this opinion (if the like have not occurred to you) I will give in my next" (Sparks' *Life of Franklin*, vi, 79).

The reasons are stated as follows in a letter to the same correspondent, dated Philadelphia, 13th February 1749–50: "You desire to know my thoughts about the northeast storms beginning to leeward. Some years since, there was an eclipse of the moon at nine o'clock in the evening, which

I intended to observe; but before night a storm blew up at northeast, and continued violent all night and all the next day; the sky thick-clouded, dark and rainy, so that neither moon nor stars could be seen. The storm did great damage all along the coast, for we had accounts of it in the newspapers from Boston, Newport, New York, Maryland and Virginia; but what surprised me was, to find in the Boston newspapers an account of the observation of that eclipse made there; for I thought as the storm came from the northeast, it must have begun sooner at Boston than with us, and consequently have prevented such an observation. I wrote to my brother about it, and he informed me that the eclipse was over there an hour before the storm began. Since which I have made inquiries from time to time of travellers, and observed the accounts in the newspapers from New England, New York, Maryland, Virginia and South Carolina; and I find it to be a constant fact that northeast storms begin to leeward, and are often more violent there than to windward. Thus, the last October storm, which was with you on the 8th, began on the 7th in Virginia and North Carolina, and was most violent there" (*Id.*, vi, 105, 106).

Some writers quote Lewis Evans as the first person to recognize the general movement of our storms. Thus in *Weather Charts and Storm Warnings* (London, 1876, p. 80), Scott says: "The earliest notice of it [the translation of storms] which we can discover is an entry on a map of Virginia, published in 1747 by Lewis Evans, to the effect that all our great storms begin to leeward. Franklin, in 1760, followed in the same strain, but it appears that his attention had been caught at an earlier period, in 1743." Evans was a well-known geographer of the middle of the last century, and his "Map of Pensilvania, New Jersey, New York, and the three Delaware Counties" (1749) was highly esteemed. Following the fashion of those early days, certain parts of the map, of whose topography the author had little information, were occupied with legends explanatory of one matter or another; and among these statements is the following: "All our great Storms begin

to Leeward: thus a NE Storm shall be a Day sooner in Virginia than in Boston. There are generally remarkable changes in the Degree of Heat and Cold at Philadelphia every 3 or 5 Days, but not so often to the Northward. * * * Thunder never happens, but with Meeting of Land and Sea Clouds. The Sea Clouds coming freighted with Electricity, and meeting others less so, the Equilibrium is restored by snaps of Lightning; and the more opposite the Winds, and the larger and compacter the Clouds, the more dreadful are the shocks. The Sea Clouds, thus suddenly bereft of that universal Element of Repellancy, contract, and their Water rushes down in Torrents."

It seems to me very likely if not certain that Evans learned all this from Franklin, and that he wrote it on his map just as he did any other pertinent information that he could gather. The two men were both residents of Philadelphia, and Franklin's letters make such mention of Evans that we may be sure that they knew each other well. Franklin and Hare were publishers in 1755 of a little pamphlet of text that went with a later edition of Evans' map, on which, by the way, the statement about storms quoted above was crowded out by new geographic matter. Evans' statements about thunder-storms bear the clearest witness to Franklin's influence. Writing to Collinson in 1749, Franklin said: "For, if an electrified cloud, coming from the sea, meets in the air a cloud raised from the land and therefore not electrified, the first will flash its fire into the latter, and thereby both clouds shall be made suddenly to deposit water" (*l. c.*, v., 216).

We can hardly suppose that Evans, who nowhere but on the first edition of his map makes mention of the identity of lightning and electricity, was an original investigator in this subject; and as he evidently used Franklin's ideas in this matter, it is likely that he did the same with the northeast storms. I do not say this with any idea of discrediting Evans; he was an able man, as appears from his excellent geographic descriptions, which show an admirable perception of the physical features of our country.

Another of Franklin's letters on this subject was written

in London, in 1760, in which the date of the eclipse of the moon by which his attention was first called to the matter was stated to be on a Friday evening about 9 o'clock some twenty years before. The precise date of the eclipse has been fixed by his great-grandson, Bache, who, taking this letter as his guide, searched out from a list of lunar eclipses the one that occurred at Philadelphia, on a Friday evening, about 9 o'clock, some twenty years before 1760, and found that it must have been in 1743 (JOURNAL FRANKLIN INSTITUTE, xii, 1833, 300). It would seem that both Bache and Scott were not aware that Franklin had written on the subject before 1760.

Franklin's explanation of tornadoes and water-spouts also deserves mention as illustrating the acuteness of his mind. One of his correspondents maintained that water-spouts and tornadoes descended from aloft, a view that still has its advocates, though it seems to me to have no worthy foundation. Franklin knew better, for he said that the indraft which characterizes the surrounding air can have no escape save by ascent. He quotes the case of three whalers lying off Nantucket, and in the centre of the triangle that they formed a water-spout arose. The three whalers, becalmed before, then all caught a breeze and were carried toward the spout. At the spout, the air must therefore ascend. No contradiction has been given to this line of argument to the present day. The evidence generally quoted on the other side is that the funnel cloud, which characterizes the tornado and water-spout alike, descends from the heavy clouds above and strikes the earth or sea. But close observation must show the correctness of Franklin's answer to this. The descent is only apparent; the ascending current is cooled as it enters the rarefied space at the centre of the whirling storm, and its invisible vapor is condensed into visible cloud; as the intensity of the whirl increases toward the ground, the cloud grows in a right line downward faster than its particles are carried in a spiral line upward. Thus a century and a third ago, this ingenious explanation was correctly given for the appearance of descent that has deceived so many observers since then. It is a common thing

to read in accounts of tornadoes that the funnel descended and struck the ground, destroying everything in its path. This is purely a deceptive appearance ; there is no descent at all except of the outline of the cloud ; the wind is rising all the time as it whirls. Franklin not only clearly perceived this, but he suggested the main cause of the ascent as well. When the lower air is heated, he said, it becomes specifically lighter than the air above, and it is then in an unstable equilibrium ; the light lower air will rise through the heavier upper air, if it have opportunity, and in rising it forms a tornado. This is the fundamental idea that still lies at the base of all adequate theories of tornado origin.

The end of the last century and the early years of this one did not witness any notable advances in our science. Our forefathers were otherwise occupied at the time, and may be excused if they found no leisure for the study of the weather.

The fourth decade of this century marks the beginning of a brilliant period. Foremost in the names that then came to notice is that of Redfield. He was a Connecticut Yankee, and when still a young man in 1821 had his attention taken by a great storm that traversed our northeastern states. He found, by comparing notes with several random observers that, while the storm was blowing from the southwest in southern Connecticut, it was blowing from the northeast in the northern part of the state ; furthermore, that it appeared sooner in the western part of the state than it did in the eastern, thus unconsciously repeating Franklin's discovery. It flashed on his mind that all this could be accounted for by regarding the storm as a great whirlwind, rotating from right to left around an advancing centre. He mentioned the idea to several friends, but soon dropped it, and thought no more about it till some ten years later his attention was again brought to storms by a severe one that he witnessed in New York, where he was then living, and by which great damage was done to the shipping that sailed to and from that growing port. He recalled the idea

of the whirling storm of ten years before; he looked carefully over all the records that he could procure, and the result left no doubt in his mind. An account of his conclusions was published in *Silliman's Journal* for that year. We must regret his deliberation, for in the ten years that had elapsed since the idea of the whirling storm first took the form in his mind, Dové, a celebrated German meteorologist, had come to a very similar conclusion from his studies of the great European storm of Christmas night, 1821. His account of it was published in 1828. Still earlier, in this century, Colonel Capper, of the East India Company, had come to the same general conclusion, but without stating his evidence in definite terms. And as far back as 1698, an English Captain Langford spoke of the hurricanes of the West Indies as "Whirlwinds." It is somewhat doubtful if he really meant what we do by whirlwinds; he may have used the term as indicating strength, rather than circulation. But although later than all these predecessors, to Redfield belongs the credit of demonstrating what they suggested in more or less vague form. In this he clearly outranks Dové. He must be recognized as the leading original investigator of the subject. His wide grasp of the question is illustrated by the following extracts from his writings.

In his first paper in 1831, he stated that all storms, and not only the violent equinoctial hurricanes, are great whirlwinds or revolving storms, turning from right to left and gradually progressing northeastward; the winds increase in violence toward the centre of the whirl, but at the centre there is commonly a calm; the storms are regarded as gyrating portions of the atmospheric circulation in which they are carried along; and the low barometric pressure at their centre is ascribed to centrifugal force. The practical value of these conclusions in giving means of determining the bearing and probable course of the dangerous storm centre was clearly perceived. The omission of reference to any centripetal acceleration and deflective force, the reference of the origin of the storms to eddies in the trade winds caused by islands or by conflicting winds, and the explana-

tion of the storm clouds and rain by the "depression of the cold stratum of the upper atmosphere," are the chief deficiencies of this most remarkable paper. But far above these omissions stand the correct statements which appear so clearly in this first essay, full-grown.

In 1834, he reached the fine generalization that "there is reason to believe that the great circuits of wind, of which the trade winds form an integral part, are nearly uniform in all the great oceanic basins; and that the course of these circuits and of the stormy gyrations which they contain, is, in the southern hemisphere, in a counter-direction to those north of the equator" (*Amer. Jour. Science*, xxv, 121).

In 1843, Redfield made explicit mention of the law of conservation of areas in accounting for the greater velocity near the centre of the tornado (*Amer. Jour. Science*, xliii, 272), and in 1846, he refers to the same law under another name (equal areas in equal times), to explain the greatly accelerated velocity of rotation in the wind on nearing the axis of a storm (*Hurricanes and Northers*, 87).

Already in 1834, he had ascribed "the ordinary routine of the winds and weather" in the temperate latitudes to the passage of rotary storms, and the irregular variations of the barometer are referred to "the larger atmospheric eddies" (*Amer. Jour. Science*, xxv, 1834, 120, 129). Again, in 1846, the greater variations of winter temperature are shown to result from the passage of rotary storms, with warm southerly winds in their front and cold northerly winds in their rear (*Hurricanes and Northers*, 102). This is the beginning of the understanding of our "cold waves.' In all his writings, Redfield seems to have had a thoroughly rational view of the classification of the stormy disturbances of the general circulation. Finally, under the heading, "What are Cyclones?" he wrote in 1854, "The term cyclone was first proposed by Mr. Piddington to designate any considerable extent or area of wind which exhibits a turning or revolving motion, without regard to its varying velocity or to the different names which are often applied to such winds. * * * Thus, all hurricanes or violent storms may perhaps be considered as cyclones or revolving winds.

But it by no means follows that all cyclones are either hurricanes, gales or storms. The word is not designed to express the degree of activity or force which may be manifested in the moving disc or stratum of rotating atmosphere to which it is applied. It often designates light and feeble winds, as well as those which are strong and violent. * * * The more inert and passive cyclones which seldom gain attention, but which constantly occupy in their transit the greater portion of the earth's surface, appear to move in orbits or courses corresponding with those of the more active class which have been traced on the storm charts. * * * In a broad view of the case, the constant occurrence and progression of the cyclones in various degrees of activity constitutes the normal condition of the inferior or wind stratum of the atmosphere, at least in the regions exterior to the trade winds of the globe" (*Amer. Jour. Science*, xviii, 1854, 188, 189). This has always seemed to me a truly sagacious paragraph. The generalizations here announced were overlooked or disputed by many European writers, and were never admitted by Dové, who after making a brilliant beginning as a competitor of Redfield's, afterward failed to keep pace with him on this subject. But Redfield's ideas, although not known as his, gained more and more general currency from the time of the first publication of weather maps in France in 1864, when the essential points of his views as to the cyclonic control of weather were revived and extended by Marié-Davy.

When Redfield began his studies, he said simply that storms were rotary winds, without defining precisely what he meant by that term. The natural meaning of it was that the storm winds ran round in circles. Partly from his own studies, and probably in greater part by reason of the discussions that Espy aroused, Redfield soon made more precise statements in this matter. After the first paper of 1831, in which the diagram showed circular winds, a chart dated 1835, published in 1837, contains diagrams which indicate the spiral course of the winds, now generally recognized, but the text implies only horizontal circuits. In 1839, he wrote, "in the most violent of these storms, it is at

least probable if not certain, that the course of the surface wind is spirally inward, approximating gradually toward the centre of the storm" (xxxv, 204). Finally, in 1846, we come upon the often-quoted passage, here again repeated. "When, in 1830, I first attempted to establish by direct evidence the rotative character of gales or tempests, I had only to encounter the then prevailing idea of a general rectilinear movement in these winds. Hence I have deemed it sufficient to describe the rotation in general terms, not doubting that on different sides of a rotary storm, might be found any course of wind from the rotative to the rectilinear. But I have never been able to conceive that the wind in violent storms moves only in circles. On the contrary, a vertical movement approaching to that which may be seen in all lesser vortices, aërial or aqueous, appears to be an essential element of their violent and long-continued action, of their increased energy toward the centre or axis and of the accompanying rain. In conformity with this view, the storm figure on my chart of the storm of 1830 [to which reference is made above], was directed to be engraved in spiral or involute lines, but this point was yielded for the convenience of the engraver. The common idea of rotation in circles, however, is sufficiently correct for practical purposes and for the construction of diagrams, whether for the use of mariners or for determining between a general rectilinear wind on the one hand or the lately alleged centripetal winds on the other. The degree of vorticular inclination in violent storms must be subject locally to great variations; but it is not probable that on an average of the different sides, it ever comes near to 45° from the tangent to a circle, and that such average inclination ever exceeds two points of the compass, may well be doubted" (*Hurricanes and Northers*, 1846, 16).

At a little earlier date, he wrote, "In most gales of wind there is, probably, a subordinate motion, inclining gradually downward and inward in the circumjacent air, and in the lower portions of the gale; and a like degree of motion, spirally upward and outward, in the central and higher portions of the storm. This slight vorticular movement is

believed to contribute largely to the clouds and rain which usually accompany a storm or gale, and is probably due, in part, to the excess of external atmospheric pressure on the outward portions of the revolving storm" (*Trans. Amer. Phil. Soc.*, viii, 1843, 79).

The effect of another's teaching is clearly seen here, and to him we now turn our attention.

Contemporary with Redfield was Espy, as original in his line of work, but following very different methods. Espy was a theorizer; his work was largely deductive, and his writings contain continued mention of his theories. His style is positive and aggressive: "I do not submit to authority," he said. Although not always right, he had an extraordinarily clear insight into certain processes which had been but little understood by his predecessors; many of his contributions still hold their place in our science; some have even been independently rediscovered, and have given high credit to their new advocates, after Espy's share in their announcement had been forgotten.

The central idea that dominated all Espy's work was the change of temperature that is produced in the ascending or descending members of a convectional circulation. The idea of convectional circulation had long been stated; we have already met an illustration of it in Franklin's explanation of tornadoes. Espy took this up, enlarged and extended it almost to its modern development. Especially in connection with the changes of temperature in bodies of moist air were his theories of novelty and value; his quantitative estimates of certain processes was exaggerated at first, but approached accuracy later on. He ascribes the beginning of his advance to the time when it occurred to him to calculate the effect which the evolution of latent heat produces during the formation of cloud. "The result was an instantaneous transition from darkness to light. The moment I saw that a rapidly forming cloud is specifically lighter in proportion as it becomes darker, a thousand contradictions vanished,

and numerous facts, ' a rude and undigested mass,' which had been stowed away in the secret recesses of my memory presented themselves spontaneously to my delighted mind, as a harmonious system of fair proportion." This is from the preface of his *Philosophy of Storms* (iv), published in 1841; on the same page he recommends his readers to dwell on the synopsis that follows, it being the essence of his theories, in form prepared for presentation to the British Association the year before.

Many a modern observer of the weather would profit by following this recommendation. Indeed, the statements lately made by Dr. Julius Hann, of Vienna, the leading meteorologist of Europe to-day, is strong testimony to the value of Espy's work; he says: " When several years ago (1881) I first * * * read Espy's works over more carefully, I saw to my astonishment that this eminent meteorologist, who has never been appreciated in proportion to his services, had announced a great number of those principles which we are now accustomed to consider as acquisitions of the so-called modern meteorology; and this not as casual suggestions, which under scientific criticism have hardly any value, but as the results of correct physical theory, tested by observations" (*Meteorol. Zeitschrift*, ii, 1885, 393).

(*To be continued.*)

TECHNICAL ITEMS OF INTEREST.

[*Abstract from the Report of the Secretary, presented at the Annual Meeting of the* INSTITUTE, *held Wednesday, January 16, 1889.*]

MEASURED by the volume of commercial operations, and by the degree of activity that prevailed in nearly all branches of the manufacturing industries, the year 1888 may be reckoned a fairly prosperous one. As compared with the previous two years, however, the figures of production of our iron and steel industries exhibit a decrease, although in the aggregate the volume of production is high, and the fact that our output of coal in 1888 was the largest in our history is satisfactory evidence of general prosperity.

As has been our custom in former annual reviews, we shall rely for the facts and figures respecting the American iron trade, upon data collected and arranged by Mr. Swank, the able statistician of the American Iron and Steel Association, and from the brief summary which he has made public in the Association's *Bulletin*, the following facts and comments are taken.

"The past year has been one of lessened activity in the iron trade of this country as compared with 1887, but if mere production be considered it will be found, with one important exception, to have been fully as active a year as 1886, which was the most productive year in our iron history. Both 1886 and 1887 were booming years for the American iron trade, but the latter was not only more productive than the former, but it was also a more prosperous year.

"Our total production of pig iron in 1886 was 5,683,329 gross tons; in 1887 it was 6,417,148 tons; in 1888 it has been the largest in our history and is probably about 6,500,000 gross tons. A decrease in 1888 was made in the output of Bessemer pig iron. The total production of steel rails in 1888 by the American Bessemer works was 1,528,057 net tons, or 1,364,337 gross tons, against 2,290,197 net tons, or 2,044,819 gross tons, in 1887—a decrease in 1888 of 640,482 gross tons, a shrinkage which is greater than our total production of steel rails in 1879, when 610,682 gross tons were made. The decreased production of 1888, as compared with the production of 1887, was almost exactly thirty-three and one-third per cent. The production in the last half of 1888 was less than in the first half. The consumption of steel rails in 1888 was fully 750,000 gross tons less than in 1887, the imports in 1888 having declined about 77,000 tons as compared with 1887. In 1887 they amounted to 137,588 gross tons, and in 1888 to about 60,000 gross tons.

"In the production of bar iron and plate and sheet iron, and in the aggregate production of cut and wire nails, the figures for 1888 will not vary greatly from those for 1886, while our production of structural iron and steel was greater in 1888 than in 1886 and probably greater than in 1887. This country has in late years developed a large demand for iron and steel for all structural purposes, particularly in the erection of public buildings.

"The consumption of iron and steel in the United States in 1888 was much less than the estimated figures of production which we have given would indicate. While our importations of iron and steel in 1888 were nearly, if not altogether, 950,000 gross tons, they nevertheless fell far below the importations of 1887, which reached the enormous aggregate of 1,783,251 tons. With reduced production and reduced importations of iron and steel, exact figures for neither of which will for some time be accessible, we have estimated from such data as are at hand, that our consumption of pig iron in 1888 has fallen fully 600,000 tons, as compared with 1887, and our consumption of steel rails about 800,000 tons.

"Among the industries which consume iron and steel the building of locomotives and railroad cars of all kinds has been very active all through 1888.

"The principal cause of the decline in prices in 1888, which commenced in 1887, and of the great decline in the production of steel rails, was the reaction in the building of new railroads which set in in 1887.

"Although the manufacturers of structural iron and steel of a few other specialties were fairly prosperous in 1888, it will be seen from the exact figures and the estimates we have given that the year was one of lessened production and exceedingly low prices for our iron and steel manufacturers generally. Take it all in all it was not a prosperous year for the American iron trade."

THE PRODUCTION of Pennsylvania anthracite coal during the past year reached the unparalleled figures of 38,400,000 gross tons, as compared with 34,641,017 tons in 1887, which, up to that time, was the largest output in the history of that important industry. The increase in 1888 was over ten per cent. At the present writing, the exact figures of production of the other varieties of coal are not accessible, but the unusually active condition of manufacturing in the Southern States will certainly more than make up for any falling off in the consumption in other sections, and the figures may be expected to reach 80,000,000 tons. In the figures representing our mineral industries, other than coal and iron, I shall, as heretofore, glean the data from the annual reports of the *Engineering and Mining Journal*, which summarizes the subject in the following terms:

The year just closed has been a very eventful as well as a very prosperous one to the mineral industries. The value of the mineral products, which in 1887 (including coal and iron) amounted to the enormous total of $542,284,-225, was still further increased in nearly every item in 1888, when it undoubtedly exceeded $550,000,000, or more than the aggregate value of the mineral products of all European countries.

PRODUCTION.

Iron ore (tons of 2,240 pounds),	11,400,000
Copper. Pounds,	236,000,000
Lead (tons of 2,000 pounds),	189,000
Zinc (tons of 2,000 pounds),	57,000
Silver Troy ounces,	43,000,000
Coining value. $1 29 per ounce,	$55,470,000
Gold. Troy ounces,	1,650,000
Coining value, $20.67 per ounce,	$34,105,500

AN EXAMINATION of the statistics of railway construction, during the past year, will disclose the explanation of the decided falling off in the output of the Bessemer works. The *Railway Age*, which has excellent facilities for obtaining valuable data on this point, estimates that the railway mileage of the country has increased during the past year by 7,120 miles. While this is much less than the phenomenal increase in the years 1887, 1886, 1882 and 1881, when the new mileage was respectively 13,080, 8,999, 11,568 and 9,796 miles, the record for the past year, nevertheless, exceeds that of every other year in the history of the country, with the further exception of the year 1871, when 7 379 miles were added. As has been the case for several years, Kansas heads the list of states in the amount of new railway constructed within her borders. From the same source above-named, we are informed that in the last three years about 4,400 miles of railway have been built in this single state. Taken by geographical groups, it appears that the twelve states of the Southern group lead with 2,074 miles, or nearly thirty per cent. of the entire new mileage; the ten great Southwestern States and Territories come next with 1,675 miles; the seven Pacific Coast States and Territories show 1,055 miles; the five rich and populous states of the Central Northern group follow close with 1,030 miles; the six immense states and territories of the Northwest add only 834 miles; while all New England and the neighboring Eastern States contribute but 452 miles.

There were obvious signs, toward the close of the year 1887, that the culmination of the period of rapid railway expansion, which began to make itself manifest in 1885, had been reached, and that the year 1888 would exhibit a marked decrease. The fact that the greater portion of the new mileage of 1888 was built in the first half of the year, makes it very evident that much of the work represented the completion of contracts entered into prior to the beginning of the year. The present prospects of the railways are by no means favorable to the investment of capital in the construction of new lines, and we anticipate that the figures for the current year will exhibit a further shrinkage in amount.

IN THE FIELD OF ENGINEERING, the notable event of the past year was the collapse of the Panama Canal project, by reason of the financial failure of the company. This event had long been looked for, and its happening, therefore, was in a measure prepared for, and created, consequently, less disturbance than many anticipated. The failure will undoubtedly cause great distress, and its worst results may not be immediately apparent. What will be the ultimate fate of this ill-considered and wofully-mismanaged enterprise it is at present quite impossible to foresee, since its prosecution by a new management seems to be surrounded by serious complications.

One of the oldest engineering projects in the world is now gradually approaching completion, and the work will probably be finished during the present year. This is the canal through the Isthmus of Corinth, in Greece, to which we have several times made reference in our annual reviews. This

work was first planned some twenty-five years ago, and work was actually begun under the Emperor Nero, so that over 1,700 years will have passed between its beginning and its final completion. As finally excavated, the canal will be four miles long, with a depth of eight metres, or sufficient for the largest vessels which usually navigate the adjacent seas. The total cost of the canal will be about $9,000,000, or $4,000,000 more than the original estimate. The work, it is stated, has been very substantially done, and the cost of maintenance will probably be very light. It has been carried out under the direction of French engineers.

Work on the Manchester Canal, referred to in last year's summary, has been vigorously prosecuted. From the latest accounts of it given in the English technical papers, it appears that there are employed upon it 8,568 men and boys, 51 steam navvies, 98 locomotives, 49 steam cranes, 3,221 wagons, and 104 pumping and other engines.

Work upon the vast structure which will bridge the Firth of Forth is being rapidly pushed, and its completion may shortly be looked for. As this will be by far the largest engineering work of its kind, a specification of its dimensions may not be out of place as a matter of record: The total length of the viaduct will be 8,296 feet, or nearly one and five-eighths miles, and there are two spans of 1,710 feet, two of 680 feet, fifteen of 168 feet girders, four of fifty-seven feet, and three of twenty-five feet, being masonry arches. The clear headway for navigation will be not less than 150 feet for 500 feet in the centre of the 1,710 feet span. The extreme height of the structure will be 361 feet above the extreme depth of foundations, ninety-one feet below the level of the water. The main piers, three in number, consist each of a group of four masonry columns faced by granite 49 feet in diameter at the top, and 36 feet high, which rest either on the solid rock or concrete carried down in some cases by means of caissons of a maximum diameter of 70 feet to the rock or boulder clay, which is almost of equal solidity. The rolling load has been taken as one ton per foot run on each line of rails. The wind pressure provided for is fifty-six pounds per square foot, the total amount on the main spans being estimated at nearly 8,000 tons. The material used throughout is open-hearth or Siemens-Martin steel. The superstructure of the main spans is made up of three enormous double cantilevers resting on the three piers mentioned. Those on the shore side are 1,505 feet, and that on Inchgarvie 1,620 feet in length.

The past year witnessed the actual completion and opening to traffic of the great bridge over the Hudson at Poughkeepsie, certain details respecting which were included in our summary of the events of 1887. The opening of this new highway is regarded as an event of much importance to the transportation interests of the country, since it constitutes the connecting link connecting the railroad systems of New England with those tapping the coal field of Pennsylvania.

An important iron railway bridge, of the Pratt truss type, constructed for the Chicago and Northwestern Railroad, over the Missouri River at Sioux City, was opened for traffic during the past year, making the seventeenth bridge structure crossing this river.

A great scheme for the irrigation of the arid lands of the West, lying between the Rocky Mountains and the Missouri River, has been proposed by Major Powell, Director of the United States Geological Survey. There are several hundred thousand square miles of territory embraced in this region, which are now entirely unfit for cultivation. The plan involves the construction of great dams in the cañons of the rivers of the region at suitable points near the head waters, sufficiently strong to resist the flood waters of spring, behind which vast volumes of water could be impounded, and, by means of aqueducts, canals, etc., etc., distributed over the entire region as it would be needed. All that is needed to render these vast tracts fruitful is the moisture now lacking, and the plan presents magnificent possibilities. The Director believes that, by the intelligent application of his plans, not less than 150,000 square miles of now desert land could be made productive—thus increasing one-third the agricultural land of the country, which at present amounts to 300,000 square miles. Congress has granted an appropriation for the expenses of the preliminary surveys, and the practicability of the project will shortly be determined.

The project for an interoceanic canal across Nicaragua is in the hands of an American company owning valuable concessions from the Central American States, through whose territory the selected route will pass, and the prospects at the present time for the early commencement of the work of construction are good. The surveying expedition sent down during the past year succeeded in locating an exceedingly favorable route, by which the actual amount of canalization will be reduced from forty miles (the estimate of the plan of 1885) to about twenty-eight miles. The company at this writing is awaiting the action of Congress in the matter of its application for a national charter, respecting the grant of which, since no financial support is asked for, there should seem to be no room for objection. The estimated cost of this enterprise is placed at $50,000,000, and the time required for completion five years.

Plans are said to have been perfected for the construction of a great suspension bridge to span the Hudson River from Anthony's Nose (just above Peekskill, and south of the Highlands), on the east, to Fort Clinton on the west bank. The project is said to contemplate a single span of 1,620 feet, and the total length of the structure, including the approaches, will be 2,850 feet. The structure will leave a clear headway for navigation of 163 feet. It will have a double track for railway, and a roadway for vehicles and foot passengers beneath. Like the Poughkeepsie Bridge, this one is projected in the interest of a number of railways, for which it will establish important connections.

IN THE FIELD OF ELECTRICITY, the year just past has witnessed substantial progress in several directions. In electric lighting no remarkable inventions may be noted, and the news of the year may be summed up in the statement that the introduction of the electric systems of lighting con-

tinued steadily, as has been the case for a number of years, until to-day, as one of the electrical journals affirms, it is doubtful whether there is a city of 15,000 inhabitants east of the Mississippi which does not contain an electric lighting station.

In reference to the *telephone*, it may be noted that the long-distance lines have been considerably extended, and that the system has fully established its usefulness, having grown greatly in popular favor. The high quality of work for the proper working of the long-distance lines was signally shown during the time of the great "blizzard" of March, 1888, when they proved to be the only lines that were not disabled by the effects of the storm, and afforded for several days the only means of communication between several of the chief cities of the country, which, but for them, would have been completely cut off from intercourse with the outer world.

In *telegraphy* there is nothing to record of special interest, save, perhaps, the fact that the system of train telegraphy, devised by Phelps, Edison and others, and which was first introduced as a practical working system on the Lehigh Valley Railroad, has fully demonstrated its utility, and is now in daily use on that road.

There has been decided progress in the introduction of electric motive power. This was exhibited not only by the adoption of the electric system for street railways in cities, but in the growing employment of the electric motor for general industrial uses. Specially noteworthy is the favor with which the electric motor has been received in the great mineral regions of our Western country, where it has been applied with most encouraging results to the work of drilling, pumping, transportation, hoisting, etc., in the mines. In many cases, water-power, transmitted electrically over considerable distances, is utilized to operate these motors. The ease with which water-power, otherwise unavailable because of its inaccessibility by other methods, may thus be utilized and transmitted to any desired point within reasonable distances, promises most important practical results. In the development and application of the electric motor, we appear to have made much more progress than has been made in Europe, where comparatively little has been made.

As an item of interest, allusion should be made to the action of the Legislative Commission of the State of New York in recommending that criminals under capital sentence should be put to death by the agency of electricity. This recommendation was duly approved by the law-making powers, and goes into effect from the beginning of the present year. The subject has excited considerable discussion as to whether the direct or the alternating current would answer the purpose most effectively. Thus far there has been no opportunity of testing the question.

In the field of electro-metallurgy there was great activity, and substantial progress in certain directions was shown. The electric-smelting process of the Cowles Brothers has firmly established its value in the metallurgical arts, and, thanks to it, the engineering world is now able to command the valuable alloys of aluminium and silicon at a price low enough to

permit of their extensive employment in the constructive arts. During the past year, a plant for operating the Cowles process on a large scale was completed and put in operation in England.

The Herault process, for producing aluminium alloys by an electrical reduction process, which presents some points of similarity to that of the Cowles Brothers, was put in operation on a commercial scale during the past year in Switzerland. The process in question differs from that of the Cowles in some important details of the apparatus employed, and also, it is affirmed, in respect of the principle of the method itself, though on this last point it would be prudent to suspend judgment. The *rationale* of the operation going on in the Cowles furnace is involved in some doubt, and it cannot be said with certainty whether the reduction of the ores is effected by electrolysis, or simply by the prodigiously high heat generated by the passage of the powerful electric currents through a conducting medium of high resistance; or whether both of these operations are involved. The statement that the Cowles process can be operated as well by an alternating current as by a direct current, has been urged as indicating that electrolysis played, at most, only a subordinate part in the operation; but in the light of recent observations, this argument may prove a fallacious one. The Herault process, however, is strictly an electrolytic one, as will appear from the following concise account: The electric current is employed to fuse the metal with which the aluminium is to be alloyed, and to separate the aluminium by electrolysis of alumina in a molten state. The metal, copper, for the production of aluminium-bronze, is introduced in a divided state into a crucible formed of conducting carbon, suitably strengthened by external casing of metal, this crucible forming the negative pole of the electrolyzing bath, the positive pole being composed of a bundle of carbon plates. After the copper is fused, alumina is introduced into the crucible, where it is fused and electrolyzed, the oxygen passing off at the positive pole, and the aluminium at the negative, and there uniting with the fused copper; the process is thus continuous, the fused alloy being drawn off by means of a plugged hole at the bottom of the crucible, and fresh copper and alumina being introduced by suitable openings in the cover of the crucible as required. This process is said to be operated on a large scale.

Worthy of notice in this place also, is the process of Watt, for refining impure zinc by electrolysis and for reducing the metal from its ores by electrical deposition; and that of Möbius for refining argentiferous matter, which the reader will find fully described in the technical journals.

A most interesting application of electrolysis is the process devised by Elmore, and put in operation last year in England, for the production of copper pipes by electro-deposition. By this process, seamless copper pipes, of any diameter, length and thickness are formed by depositing the metal electrolytically from a bath of acidified sulphate of copper, upon a mandrel. This mandrel is continuously rotated at a uniform rate, and the spongy copper deposited thereon is consolidated by the ingenious expedient of causing a burnisher, formed of a piece of smooth agate, to travel along the entire length of the mandrel backward and forward. By this means, the pipe

formed on the revolving mandrel is quite homogeneous, and the copper of which it is formed exhibits a remarkably uniform tensile strength of about twenty-two and three-fourths tons tensile strength per square inch section, no matter in which direction, longitudinally or transversely to the tube, the test be made. Lately, Mr. Elmore has devised a simple and ingenious method of producing a wire from these electrically-formed tubes, by cutting therefrom spirally, an endless, slender rod of square section, which is drawn down to any desired gauge. The advantage of this method lies in the fact that it avoids the necessity of melting the metal, by which, as electricians are aware, the conductivity of electrically-deposited copper is notably diminished.

Substantial progress was made during the year by the construction of special machines, and by otherwise improving the details of the operation, in adapting the process of welding by electric current, to meet the requirements of practice. Reference is made here to the process and apparatus devised by Prof. Thomson, of which great expectations are entertained.

IN THE FIELD OF CHEMICAL TECHNOLOGY, perhaps the most interesting event of the year was the establishment and starting in operation, near Birmingham, in England, of a large plant for the commercial production of sodium and aluminium by the process of Castner, which has received frequent notice at our hands, and was referred to in favorable terms in our summary of progress for the previous year. Concerning the success of Mr. Castner's procedure for producing sodium more cheaply than by any process heretofore known and used, there can be no question. The method was exhaustively tested in an experimental works erected for the purpose, and the erection of the Oldbury works followed upon the favorable report of the experts who were engaged to conduct the preliminary examination of its merits. The Oldbury works now comprise a Castner sodium plant of twenty pots, with a maximum capacity of 1,500 pounds of sodium per day; a Weldon chlorine plant for the production of the anhydrous double chloride of sodium and aluminium used for the production of the aluminium metal, comprising twelve furnaces, with a collective capacity of 6,000 pounds of chlorine per day; and a reduction furnace, in which the actual production of the metal is effected. The capacity of the works, when fully in operation, will be, according to published advices, 500 pounds of aluminium metal daily. The product of the works will comprise, also, the alloys of aluminium. The metal is placed on the market at $5 (twenty shillings) per pound—a reduction of nearly one-half upon its present price.

The Oldbury works were formally opened in the summer of 1888, on which occasion, in addition to those immediately interested, many eminent men of science, attracted by the interesting character of the event, were present; and, from the concurrent testimony of the English technical press, the conclusion seems to be warranted that Mr. Castner has met with substantial and deserved success in the introduction of his process on a commercial scale.

The growth of the ammonia soda process, in recent years, has made the

position of the Leblanc soda makers more and more precarious by reason of the severity of its competition, and this fact lends a special importance to every method which promises to introduce economies in the operation of the older process of manufacture, in which an enormous capital is engaged. For these reasons, the chemical world has received with interest the announcement, by Mr. Chance, to the Society of Chemical Industry, of a process for the recovery of sulphur from alkali waste by means of lime-kiln gases, which may take rank as a fundamental improvement of the Leblanc soda process. Mr. Chance claims to recover, either as brimstone or as sulphuric acid, ninety-five per cent. of the sulphur previously wasted in the calcium sulphide of this method of soda making; and as the quantity of pyrites used exclusively for this industry (the sulphur of which is now thrown away) is estimated at 300,000 tons annually, the importance of the new method, should it realize the hopes of its friends, may mean the salvation of the Leblanc process.

A modification of the Weldon process for the manufacture of chlorine, called from the name of its inventor the Weldon-Pechiney process, is attracting attention. It has been introduced at Salindres (France) in an experimental way, with a plant of the capacity of one ton of chlorine per day, and the results may indicate that another pronounced improvement in one of the fundamental chemical industries has been made. For the details of this process, which produces no waste products, and involves the ultimate regeneration of the material (magnesium oxide) employed at the starting point, to serve indefinitely through the same series of operations, the reader is referred to the technical journals.

In metallurgy, a notable event of the past year was the publication of an important paper by Mr. Keep, of Detroit, giving the results of a careful series of experiments upon the influence of additions of aluminium to cast irons, with special reference to the improvement of inferior irons by such additions, so as to adapt them to foundry uses. The results of these investigations appear to establish the fact that small additions of aluminium (in the form of ferro-aluminium), up to one per cent., exert a distinctly favorable influence on cast iron, permitting the production of soft and faultless castings from irons heretofore regarded as altogether unfit for foundry use. Some question has been raised as to whether the results noted by Mr. Keep should not be attributed, at least in part, to the silicon in the aluminium alloy he employed; but the preponderance of evidence appears to be in favor of the view that the influence of small additions of aluminium to cast iron is no less marked and favorable than it is known to be in the case of wrought iron. The interest excited by the announcement of these results is shown by the fact that a considerable demand has lately sprung up for ferro-aluminium for foundry use. Should Mr. Keep's results be verified in practice, they will prove of the highest importance to foundrymen.

It is worthy of notice, in connection with the unusual share of attention that has of late been given to the subject of the cheap production of aluminium, that the general sentiment among metallurgists respecting the practical value of this metal has undergone a considerable modification. Sober

second thought, now that the day of cheap aluminium appears to be drawing nigh, has dispelled many of the extravagant notions that formerly were entertained, even by men of science, respecting the possible utilities of this elusive metal. The more carefully its properties are studied, the more probable does it appear that it will always hold a subordinate place in the arts, and that its greatest utility will be derived from its alloys, which, with diminishing cost of production, will come into very general use in the arts of construction.

The effect of the presence of manganese in steel has been made the subject of careful study, and it is believed that the constructive arts will shortly be the gainers by the possession of a metal possessing altogether new and highly valuable properties. The most interesting results have been obtained with steel containing as much as ten to fourteen per cent. of manganese. It has been found with this material, that notwithstanding its considerable toughness when cast in the ordinary way, an extraordinary gain in strength is obtained by methods, which, in the case of ordinary steel, would cause brittleness, water-cracking, and other defects. The process is termed "water-toughening," and consists in heating the article under treatment to about 1,800° or 2,000° F., and then plunging it into cold water. The nearer the above temperatures are approached, and the colder the water, the tougher will be the material. After water-toughening, notwithstanding their hardness and stiffness, it was found that test specimens could be bent double, cold, almost in the same way as a piece of the mildest forged steel, thus proving that the new alloy combined the apparently contradictory qualities of hardness and toughness. It is believed that manganese steel treated by this toughening process will be found especially well adapted for railway car-wheels, car-couplings and similar uses.

An ingenious artifice that has lately been successfully put in practice at Shenandoah by the Reading Company, at the Kohinoor colliery, for refilling the excavations from which coal has been taken out, is worthy of mention, since it is desirable that it should be imitated elsewhere throughout the coal regions where similar conditions prevail. The method is both simple and effective, and prevents the caving in of the earth above, and the consequent loss of valuable property, which has not been infrequent in the mining towns of the anthracite region. Besides, the valuable pillars of pure coal, which for many years it was customary to leave in the mines, to prevent falling in of the roof, can now be taken out without fear. A coal dirt conveyer, consisting of a series of semicircular chutes, similar to those used in discharging coal from carts into cellars, and an endless chain with scrapers attached, automatically conveys the fine refuse from the coal breakers to an elevation, from whence it is discharged into a second chute. As the coal dirt falls on this, water, pumped from the mines, mixes with it and carries the stuff, in a semi-liquid state, back through a jig or puddling hole into the bowels of the earth, from whence the coal has been removed. The coal dirt settles to the bottom of the breasts and packs closely, and the water seeks an outlet below, to be

again pumped out to repeat its duty. The cost of this puddling the refuse matter back into the mines, about three to four cents per cubic yard, is very small compared with the value of the pillars of marketable coal of which the mines may be safely "robbed," and the security obtained for dwellings and railroad property on the surface, above the mines. Already more than two acres beneath the city of Shenandoah, from which the coal had been mined, have been again solidly refilled with the coal dirt which used to be piled mountains high around the town.

Public interest was aroused last year to an unusual degree by the announcement that Mr. Edison had succeeded in greatly improving the efficiency of the phonograph. These improvements, it subsequently appeared, consisted in the substitution of a specially prepared sheet of wax, into which the sound record was cut, in place of the strip of tin-foil on which a stylus made the sound record by means of a series of indentations. Other improvements related to the mechanical details of the apparatus. It should be added, however, that the claims of Edison as to priority of invention of the most important element of improvement—that is, the mode of making the sound record—were questioned by Messrs. Bell & Taintor, the inventors of the instrument called the "graphophone."

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, January 15, 1889.*]

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, January 15, 1889.

Mr. H. PEMBERTON, Jr., President, in the Chair.

Members present: Dr. L. B. Hall, Dr. H. W. Jayne, Dr. S. C. Hooker, Dr. Wm. C. Day, Dr. Wm. H. Wahl, Dr. S. P. Sadtler, Prof. Henry Trimble, Dr. H. F. Keller, Messrs. T. C. Palmer, W. L. Rowland, A. T. Eastwick, J. M. Newbold, Prof. R. L. Chase, Dr. Wm. H. Greene, Dr. D. K. Tuttle, and three visitors.

Mr. Pemberton, on taking the Chair, proposed a vote of thanks to the retiring officers for their efficient services.

The Committee on By-Laws reported progress.

The following gentlemen were elected members of the Section: Mr. F. C. Lewin, 1011 Spruce Street, Philadelphia; Mr. C. V. Petraeus, 231 South Front Street, Philadelphia; Mr. R. E. Fisher, 2239 St. Albans Place, Philadelphia; Dr. Wm. H. Greene, 204 North Thirty-sixth Street, Philadelphia; Dr. Geo. A. Koenig, University of Pennsylvania, Philadelphia; Mr. M. Carey Lea, 530 Walnut Street, Philadelphia; Prof. Henry Morton, Stevens Institute, Hoboken, N. J.

The following gentlemen were nominated for membership in the Section: Dr. T. R. Wolf, Newark, Del.; Mr. C. J. Semper, 505 South Forty-first Street, Philadelphia; Mr. S. Lloyd Wiegand, 146 South Sixth Street, Philadelphia; Prof. Edgar F. Smith, Ph.D., University of Pennsylvania; Mr. Marshall R. Pugh, University of Pennsylvania.

Dr. Wahl announced that papers read before the Section could be published in the JOURNAL OF THE FRANKLIN INSTITUTE, simultaneously with other journals, and that such articles would be continuously paged so as to form an independent work, which would be bound and issued as such by the Section.

The matter of obtaining a suitable desk for the benefit of the Secretary of the Section was referred to the conservator with power to act.

Notice was given by the President proposing an amendment to the By-Laws, making the annual dues $2 per year instead of $1 as heretofore.

The President appointed Drs. Greene, Hooker and Hall members of a Committee on Abstracts, the duty of the committee to consist in selecting from the various chemical journals articles to be abstracted, and in assigning such articles to the various members of a volunteer committee, by whom they are to be abstracted for the JOURNAL OF THE INSTITUTE.

Dr. Wahl announced the purchase of a complete set of the *Jahresbericht* for the Library of the INSTITUTE.

Dr. Hooker showed several specimens of the pyrrol, indol and carbazol groups, and spoke briefly on the relations of these compounds to each other. The "fir-wood" reaction was strikingly shown with pyrrol, phenyl-pyrrol and carbazol, and the best way of making it explained. Dr. Hooker called attention to the fact that pine was slowly colored bright green by concentrated hydrochloric acid. This he believed had not been previously observed. A pine splinter, moistened with an alcoholic solution of furfural, was also shown to turn intensely green when exposed to the action of hydrochloric acid gas, but this could be readily distinguished from the action of hydrochloric acid alone.

Adjourned. WM. C. DAY, *Secretary.*

[*Erratum.*—In list of nominations for membership in December Proceedings, for Henry C., *read*, M. Carey Lea.]

REPORT OF THE CHEMICAL SECTION, FRANKLIN INSTITUTE, 1888.

MR. JOSEPH M. WILSON, PRESIDENT FRANKLIN INSTITUTE:

SIR:—I have the honor to submit the following report of the proceedings of the Chemical Section for the year 1888:

The work of the Section was carried on with the aid of the following

OFFICERS:

President—Mr. J. H. Eastwick.

Vice-Presidents—Prof. S. P. Sadtler, Mr. H. Pemberton, Jr.

Secretary—T. C. Palmer.

Treasurer—Mr. Chas. Bullock.

Conservator—Dr. Wm. H. Wahl.

Stated meetings were held on the second or third Tuesdays of February, May, June, September, October, November and December, and special meetings were held on April 24th and June 4th, making in all nine meetings during the year.

There has been a growing interest in the affairs of the Section on the part of members, and at the present time the indications of future development and increasing usefulness and importance are very marked.

The net increase of membership during the twelve months is nine, making a total of sixty-four members.

Several matters of importance have claimed the attention of the Section during the past year. Three subjects were submitted by the Committee on Science and the Arts, and reported upon by committees of the Section, to wit:

The reopened question of the Hyatt Pure Water Company's filtering apparatus, referred back on account of a protest against the award of the Scott Legacy Medal and Premium thereto; the Sodium Process of Mr. Hamilton Y. Castner, the Hydrogen Process for Preserving Iron and Steel.

These reports were forwarded to the Committee on Science and the Arts, and are now filed among their papers.

The further proceedings of the Section are given in abstract in the following record:

An arrangement has been made, whereby the proceedings of the Section shall be published in full, in successive numbers of the JOURNAL OF THE FRANKLIN INSTITUTE, and the minutes of the December meeting, together with several papers, have already appeared in the previous impression.

ABSTRACT OF PROCEEDINGS, 1888.

Stated Meeting, February 14th.—Dr. E. H. Keiser gave an account of his work on the estimation of the atomic weight of oxygen. The method followed was the burning of hydrogen occluded by palladium, and weighing of resulting water. Results showed $O < 15 \cdot 96$. Adjourned.

Special Meeting, April 24th.—The Treasurer's report for 1887 was read. Bills were ordered to be paid. Resignations of Dr. J. B. Lober and Mr. Bruno Terne were accepted. Nominations of four gentlemen to membership were made. The deferred election of officers took place. The President announced the following committees: (1) *On the Castner Sodium Process*, Dr. E. H. Keiser, Messrs. Weikel and Palmer. (2) *On the Hydrogen Process for Preserving Iron and Steel*, Dr. Wm. C. Day, Messrs. Matos and Chase. Amendments to By-laws were announced. Dr. E. H. Keiser spoke further of his work on the atomic weight of oxygen. Further results had shown the probable correctness of the usually accepted number, 15·96. Adjourned.

Stated Meeting, May 15th.—The resignation as member of the Section of Mr. L. W. Moody was accepted. The committees appointed at last meeting reported progress, and were continued. Mr. Victor de Balas, Dr. D. K. Tuttle, Dr. Samuel C. Hooker, and Mr. Geo. C. Webster were elected to membership. The protest of Prof. A. R. Leeds against the report of a committee of this Section, on the Hyatt Pure Water System, together with said report and correspondence concerning the subject, was read, and, on motion, the matter was made a special order for an appointed meeting of the Section. Adjourned.

Special Meeting, June 4th.—The protest of Prof. A. R. Leeds against the favorable report of the Committee on the Hyatt Pure Water System, was read; also, the report in question, and various letters and documents bearing on the matter. After a very full discussion, it was

Resolved, That the Secretary be instructed to inform the Committee on

Science and the Arts, that the Chemical Section, acting as Committee of the Whole, has carefully considered the protest of Prof. A. R. Leeds against the award of the Scott Legacy Premium and Medal to the Hyatt Pure Water Company, and does not deem the evidence submitted of sufficient importance to warrant it in recommending a re-opening of the question.

Dr. E. H. Keiser read the report of the Committee on the Castner Sodium Process. The report concludes with the following: "It appears, from all the evidence submitted to us, that, through the efforts of Mr. Castner, an advance step has been taken in the manufacture of sodium, which cannot help having a beneficial effect on industry." The report was adopted. Dr. Wm. C. Day read the report of the Committee on the Hydrogen Process for Preserving Iron and Steel. This report contained a description of the process, but stated that the committee had been unable to obtain any evidence of its successful working. Accepted. Adjourned.

Stated Meeting, June 19th.—Bills for printing were ordered to be paid. Dr. H. W. Jayne read a paper on "Coal Tar Products." The paper was illustrated by numerous specimens and drawings. The lecturer spoke particularly of the present state of manufacture and various uses of naphthalin, giving many facts and circumstances of great interest. On motion of Prof. N. W. Thomas, a vote of thanks was tendered Dr. Jayne for his unusually interesting paper. Adjourned.

Stated Meeting, September 18th.—Routine business and general discussion. Adjourned.

Stated Meeting, October 16th.—Dr. Samuel C. Hooker read a paper on "Estimation of Nitrates in Natural Waters, and Some New Reactions of Carbazol." A general discussion of the paper followed. Adjourned.

Stated Meeting, November 20th.—Two gentlemen were nominated for membership in the Section. Treasurer was authorized to receive subscriptions to JOURNALS for the year 1889. Nominations of officers for the year 1889 were made. Mr. H. Pemberton, Jr., spoke of a constant error found by him in a line of burettes made by Greiner, of New York, due to the graduation having been made with the aid of mercury, the meniscus of which is different from that of water. Dr. Jayne described the extensive color works at Basle, and laboratories connected with them; spoke also of the vast extent of the color market in China and Japan, due to the practice of household dyeing. The commercial peculiarities of the color trade of Europe were also described. Miscellaneous discussion. Adjourned.

Stated Meeting, December 18th.—Two gentlemen were elected members of the Section, and seven nominated. The following were elected officers for 1889:

President—Mr. H. Pemberton, Jr., 1947 Locust Street, Philadelphia.

Vice-Presidents— { Dr. S. C. Hooker, Franklin Sugar Refinery, Phila.
Mr. T. C. Palmer, 22 North Front Street, Philadelphia.

Secretary—Dr. Wm. C. Day, Swarthmore College, Delaware County, Pa.

Treasurer—Dr. H. W. Jayne, Bermuda Street, Frankford, Philadelphia.

Conservator—Dr. Wm. H. Wahl, FRANKLIN INSTITUTE, Philadelphia.

Mr. Pemberton presented a communication from Dr. Wahl, concerning the publishing of papers of the Section. Committee to confer with Dr. Wahl, Mr. Pemberton, Jr., Dr. S. C. Hooker. Committee to revise By-laws and membership list: Mr. T. C. Palmer, Dr. H. W. Jayne, Prof. R. L. Chase. Mr. Lüthy exhibited and remarked on the mineral eudialyte. Prof. Chase and Dr. Jayne discussed the film of the Welsbach gas burner. Dr. Hooker showed samples of so-called electrically refined sugar. Mr. Luthy agreed with him in his estimate of the alleged electric process. Mr. Macfarlane exhibited a souvenir of the twenty-fifth anniversary of the color works of Meister, Lucius & Bruening. Dr. Hooker showed a sample of saccharin and described the most reliable test for it. Discussion of the wholesomeness of saccharin, by Dr. Hooker, Dr. Jayne, Dr. Hall. Adjourned.

Respectfully, T. C. PALMER, *Secretary.*

ON THE ASH OF TILLANDSIA USNEOIDES.

BY T. C. PALMER.

[*To be read before the Chemical Section*, FRANKLIN INSTITUTE, *February 19, 1889.*]

At the suggestion of Prof. H. Trimble, I have made an analysis of the ash of Florida long moss, with results that are perhaps worthy of publication.

About the year 1835, Avequin of New Orleans, published* an analysis of this ash, in the following terms:

1,000 grammes of moss gave 32·35 grammes ash.

[Ash = 3·235 per cent.]

Composed of—

	Grammes.
Salt of potash (phosphate, sulphate, carbonate, chloride),	11·47
Lime, partly as carbonate,	5·96
Phosphates of lime and magnesia,	9·26
Silica containing a little iron and manganese,	5·66
	32·35

This seemed to be the only analysis hitherto made of the ash, and it is very incomplete.

The results obtained by me are given as the average of two concurring analyses, and are as follows:

* *Journal de Pharm. et Chimie*, iii, 35, 95.

Total ash, 2·95 per cent., the dried plant.

PERCENTAGE COMPOSITION.

	Per Cent.
SiO_2,	10·3000
Fe_2O_3,	2·100
Al_2O_3,	2·600
MnO,	1·672
CaO,	12·700
MgO,	11·351
K_2O,	13·759
Na_2O,	14·856
SO_3,	7·419
Cl,	6·947
CO_2,	12 900
P_2O_5,	3·034
Total,	99·638

It is rather difficult to compare these two analyses, on account of the difference in the way they are recorded; but in the two cases where I have tried grouping some of the constituents in the manner of Avequin, the agreement is close enough to show that in all probability, nearly identical results have been reached in the two cases. So far as it goes, this is proof of the *à priori* idea that the ash of this plant is practically, and within certain limits, uniform, regardless of where it grows. Avequin gathered his sample near New Orleans; that selected for the above analyses came from Florida.

It is my desire to point out that here we have an anomaly of a certain sort. *Tillandsia* is a typical epiphyte, and according to definition should select its mineral matter, as well as its organic matter, entirely from the air. Its roots are not supposed to give it any nourishment, being merely anchors or grippers.

But unless the floating dust of the forests where this plant grows is more plentiful and more complicated in composition than we have any reason to think it, what we know of the circumstances of *Tillandsia's* growth points, in the light of these analyses, to an absorption from the trees on which it grows, of the mineral constituents at least. The presence of manganese oxide to the extent of 1·672 per

cent. of the total ash, is especially significant, for manganese has come to be looked on as a very common constituent of vegetable growths in general.* Thus it is found in notable quantities in wheat, edible roots, such as potatoes, in peas and beans, in tobacco, tea, coffee, fruits, etc., and not accidentally, but uniformly. But especially in point is the fact that manganese is very plentiful in the barks of various species of trees. Thus, two samples of the bark of *Quercus tinctoria* gave each a total ash of about three per cent. and of this, in each case, about 1·5 per cent. was manganese oxide. An extract of hemlock bark (*Abies Canadensis*) gave a total ash of 2·5 per cent., of which manganese oxide constituted 5·128 per cent. An extract of quercitron bark gave an ash of 4·98 per cent., of which 3·740 per cent. was manganese oxide. These few examples might be continued indefinitely, but they will suffice to show the abundance of manganese in barks; and, further, its presence in the extracts of the barks shows it to be in a soluble form in the barks. The other constituents are such as one finds in the bark of trees; and no single one of them is entirely anomalous in a plant. So that it would appear that *Tillandsia* does probably get its mineral food like other plants, from the earth and not from the air.

The crucial test, however, remains to be made, and I shall proceed to make it. That will consist in the analysis of some *Tillandsia* that has been grown on a support incapable of affording any mineral matter already in solution, such as a glass rod. Such an analysis will be the subject of another paper.

ABSTRACTS.

ON THE BEHAVIOR OF THE HYDRATES AND THE CARBONATES OF BARIUM AND OF THE ALKALI METALS AT HIGH TEMPERATURES.—By Prof. W. Dittmar (*Jour. Soc. Chem. Ind.*, **7**, 730). A description of the carbonates and hydrates of the above bases when highly heated in an atmosphere of hydrogen, of nitrogen, and of carbon dioxide. *Carbonate of lithia*, heated partly by Bunsen burner, partly by gas blow-pipe, for thirty-seven hours, in atmosphere of *hydrogen*, gave a residue analyzing $Li_2O = 99·57$ per cent., and $CO_2 = 0·6$ per cent., showing practically a complete decom-

* Maumene. *Bull. Soc. Chim. de Paris*, **42**, 305.

position, into oxide, due principally to the action of the hydrogen, but partly to mere dissociation, as the following experiment shows: Li_2CO_3 heated in an atmosphere of *nitrogen* to highest temperature for one hour, gave residue containing 7·77 per cent. Li_2O. Heated in same manner for ten hours, residue contained 30·37 per cent. Li_2O. Even in an atmosphere of carbon dioxide, the Li_2CO_3 was slightly decomposed, showing traces of Li_2O; and this, too, at a temperature barely sufficient to keep the substance in a state of fusion. An interesting result, however, was obtained by heating $Li\ CO_3$ in CO_2 to a red heat, *under a pressure* varying from one slightly above the normal to a full extra atmosphere (in boat in a porcelain tube). The mean of several closely agreeing experiments gave a residue containing *more* CO_2 than required, if we accept Stas' atomic weight of 7·02; the atomic weight, in fact, so deduced, being 6·909. The Li_2CO_3 used was carefully purified, but the presence of any possible impurities would have had no bearing on the argument, as the effect of such would have been to make less CO_2 present; not more.

Lithium hydrate, crystallized ($LiHO + H_2O$), lost in dry hydrogen all crystal water at 100°; the LiHO remaining undecomposed up to 320°. Heated to redness in H for four hours completely reduced to Li_2O. Crystallized *barium hydrate*, heated in hydrogen to red heat, gave in four hours pure BaO.

Barium carbonate, heated in *hydrogen* two hours by Bunsen burner, then five hours by gas blow-pipe, gave residue containing only 0·1 per cent. CO_2.

2·2168 grammes of the same, strongly heated in muffle in atmosphere of *nitrogen* for one hour, lost only 1·9 m'grs., showing great differences in the behavior in hydrogen and in nitrogen.

Sodium carbonate, heated in hydrogen, loses CO_2, leaving mixture of hydrate and carbonate, the amount of hydrate formed in four hours, by blow-pipe, varying from 11·9 to 20 per cent. Heated two hours in nitrogen residue, contained of sodium monoxide 1·759 per cent., showing slow dissociation at a red heat.

Potassium carbonate gave similar results, but with formation of smaller quantities of hydrate. The same may be said of *rubidium carbonate*. This latter salt was heated for two hours over gas blow-pipe; when the crucible was opened, it was found to be empty, showing the great volatility of Rb_2CO_3. A table of solubilities of lithium hydrate is given; also, a description of modification of Liebig's bulbs, by which loss by splashing is prevented, in passage of a quick stream of CO_2. P.

A NEW PROCESS FOR OBTAINING AMMONIUM CHLORIDE FROM THE NITROGEN OF COAL, COKE, CINDERS AND ORGANIC MATTER GENERALLY. —By Andrew French. (*Jour. Soc. Chem. Ind.*, **7**, 735.) A paper well worthy of attention. A large pile of furnace cinders, containing half-burned coal, and which had been drenched with salt water, caught fire. A stream of waste water from a fume condenser saturated with sulphurous acid was run upon it, and, in a few weeks, the fire extinguished. The interesting result of this was the formation of a large quantity of chloride of ammonium.

"It is no exaggeration to say that the surface of the heap was for the greater part covered with white, sparkling sal ammoniac, as if with snow, and, at one time, a ton at least of that salt might have been collected. In some places there were large cakes of it from an inch to an inch and a-half thick."

On digging into the heap after the fire was extinguished, an abundance of sodium sulphate was found, but scarcely any sodium chloride.

Following the advice of Prof. Dittmar, the author, tried the following experiments:

A sample of similar ashes, drenched with salt water, was burned in a Cornish assay furnace with a supply of steam, SO_2, and a limited amount of air; resulting in the profuse production of NH_4Cl. No NH_4Cl was formed if either the salt, SO_2, or steam was omitted.

Again, the nitrogenous substance was mixed with salt and iron pyrites, and made into a little brick with clay (free from N). This was then heated in a porcelain tube, and steam and air together passed through it. The following are some of the results obtained:

	Pounds NH_4Cl Per Ton.
Black's Slamannan coal,	129·6
Clyde Company's Ell coal,	101·2
Clyde Company's Jewel coal,	138·8
Coal *cinders* (coke),	96·8

Experiments on the large scale were then tried with the spent shale from a mineral oil works, in a small kiln, also with coal in the furnaces of steam boilers, using from five hundredweights to five tons of coal in the various tests, and in all cases a large yield in sal ammoniac was obtained. The author quotes several authorities, showing that the production of ammonium chloride in burning coal mines had been observed more than half a century ago. It was in 1884 that he made the observations above described, but it does not appear from this paper, that any systematic application on an industrial scale has since been made. P.

Double Bromide of Copper and Ammonia in Photography. L. L. de Koninck (*Zeitsch. f. angewandte Chemie*, 88, 507).—Bromide of copper is sometimes applied for correcting over-exposed plates. It is, however, not easily prepared, and the commercial salt is often insoluble and has not the desired effect. The author, therefore, recommends in its stead the double salt of cupric bromide and ammonium bromide, which is easily obtained in the following manner:

A weighed quantity of copper fragments are introduced into a glass-stoppered bottle and covered with about twice their weight of water. Bromine is then added by degrees under frequent shaking, until all copper is dissolved as well as any white cuprous bromide which first forms, and bromine is present in small excess.

Occasional cooling is advisable in order to prevent loss of bromine. The dark red solution is transferred to a porcelain dish and heated until the small excess of bromine is evaporated. To the remaining solution of cupric bro-

mide a corresponding quantity of ammonium bromide is now added in the relation of 2 mol. NH_4Br to mol. Cu, *i. e.*, 195·5 AmBr for 63·3 Cu or 309 for 100. After filtration the solution is evaporated to crystallize. The crystals are emerald green and well formed. The concentrated solution of this salt is wine red, the dilute like that of most copper salts, faint bluish green. A solution of 1 : 1,000 of this double salt acts with great energy upon photographic silver pictures, an over-exposed picture disappearing within a few moments. O. L.

FILTRATION AND PURIFICATION OF COLLOID PRECIPITATES BY DIFFUSION. E. Bauer (*Chemiker-Zeitung, 1888, 789*) recommends for this purpose a funnel, the lower part of which has been cut off, so that the apex of the paper filter reaches down into a body of water (or other solvent) contained in a beaker. By repeated changing the water and covering the precipitate the latter is finally completely washed. O. L.

A NEW ALKALI PROCESS.—By W. W. Staveley (*Jour. Soc. Chem., Ind.*, **7**, 807). During the last half century many attempts have been made to decompose sulphate of sodium by means of slaked lime. Even in very dilute solutions and under a high pressure, however, only a small proportion of the sodium sulphate can be so decomposed; the reason being the comparatively great solubility of sulphate of lime, in connection with the sparing solubility of calcium hydrate. The author finds, however, that by the addition of *cresol* (C_7H_8O; one of the phenols existing in oils from coal) about ninety-five per cent. of the sodium sulphate is decomposed. Any of the phenoloids may be used, those distilling between 190° and 250° C., however, being most suitable. As a practical illustration of the process, eleven hundredweights of quick-lime are slaked and sufficient water added to make a volume of, say, 400 gallons. When cold, about 430 gallons of distilled phenoloids are added, and the mixture gradually run into, say, 900 gallons of a solution of ninety-five per cent. sodium sulphate, containing about twenty-nine and three-fourths hundredweights of the latter. The mixed solutions are now agitated for several hours, at a temperature of 30° to 40° C. About ninety-five per cent. of the Na_2SO_4 has now been decomposed, with the formation of thirty-two and one-half hundredweights of $CaSO_4, 2H_2O$. The latter is allowed to settle and the solution of sodium phenolates run off, the calcium sulphate being washed on a filter. The sodium phenolate solution is now treated with carbon dioxide (from furnace fires or from lime-kiln); the phenoloids thereupon are liberated and separate as an oily fluid, floating on the surface of the sodium carbonate solution. They can now be used over again for decomposing a new lot of Na_2SO_4, as before. The Na_2CO_3 solution still contains about one per cent. of its bulk of phenoloids, and, to prevent their being carried off with the steam on evaporation, a little caustic soda is added. The Na_2CO_3 is then, after evaporation, separated as "fished salts," in the usual way, the phenoloids remaining in the red liquor (or rather in what would correspond to the red liquor, as in this case, there are no sulphides present), and are, of course, united with the main quantity

separated previously. The fished salts are calcined as usual and sold as soda ash.

By this process phenoloids are lost, (1) by mechanical adherence to the "fished salts," and (2) by retention in the calcium sulphate precipitate; the latter loss being the more important. The total loss amounts to about twenty gallons of phenoloids per ton of Na_2CO_3 produced. By using oils containing phenoloids, instead of the distilled article, the cost of the phenoloids proper would be about five pence per gallon. The net result of all of which being that about $2 worth of phenoloids must be added afresh for each ton of soda ash made. There appears to be no difficulty in obtaining an abundant supply of the oils at the above figure.

The process is, of course, as applicable to potassium salts as to sodium, and the sulphites may be used, when possible, instead of the sulphates.

The whole idea has been developed so far only on a small scale, but the above paper, in which it is described (of eight pages length), excited much interest. The application of organic compounds to the soda industry is a new departure. P.

ON THE MOLECULAR WEIGHT OF ALUMINIUM COMPOUNDS.—Roux and Louise (*Bul Soc. Chim.*, **50**, 497), have determined the vapor densities of aluminium methyl and aluminium ethyl by Victor Meyer's method in an atmosphere of nitrogen. Within 40° of the boiling points of the substances, the densities correspond exactly with the formula Al^2X^6; they then gradually diminish, and the decrease is due to decomposition of the vapors. The fact of decomposition was shown by passing the vapor of aluminium ethyl through a glass tube heated to 380°, the walls of the tube then becoming lined with a deposit of aluminium. By the method of Raoult, ethylene bromide being employed as a solvent, the molecular weights found for the ethyl, propyl and isoamyl compounds of aluminium, correspond with the molecular formula Al^2X^6. W. H. G.

ON THE PREPARATION OF CONCENTRATED FORMIC ACID.—M. Maquenne (*Bul. Soc. Chim*, **50**, 662) recommends that dilute formic acid (45–50 per cent.) be concentrated by distillation with an equal weight of concentrated sulphuric acid under reduced pressure. The acid so obtained is about eighty-five per cent. pure; loss three per cent. A second distillation of this product, with half its weight of sulphuric acid, gives an acid of ninety-eight per cent., the loss being six per cent. The temperature must not be raised above 75°, and the quantity of sulphuric acid employed must be less than that which, with the water of the formic acid, would yield the crystallizable hydrate, $H^2SO^4 + H^2O$. The formic acid retained by the sulphuric, and which constitutes the loss, may be recovered by diluting with water and redistilling.

W. H. G.

ON THE RAPID ANALYSIS OF WATER FOR INDUSTRIAL USES, WITH A VIEW TO ITS CHEMICAL PURIFICATION.—Leo Vignon (*Bul. Soc. Chim.*, **50**, 598) determines the uncombined carbonic acid by a standard solution of calcium hydroxide, so finding the amount of lime necessary to saturate the

free acid. The quantity of sodium carbonate required to throw down as carbonates the soluble salts of calcium and magnesium is then estimated by the aid of a standard sodium carbonate solution. In each case phenol-phthalein is employed as an indicator. W. H. G.

On the Detection of Salicylic Acid in Beer.—H. Elion (*Recueil de Travaux Chimiques*, **7**, 211) recommends that the beer be shaken with two or three times its volume of ether; after separation of the latter liquid it is agitated with a small quantity of slightly alkaline water. If salicylic acid be present in quantities of five to ten grammes per hectolitre, and the operation be performed on 100 cc. of beer, the reaction of salicylic acid with ferric chloride is sufficiently marked in the aqueous liquid after acidifying with hydrochloric acid. If much smaller proportions of the acid be present, the acidified aqueous liquid should be shaken out with ether, and the test made on the dry residue after evaporating the ether. The author also describes a satisfactory method for the estimation of salicylic acid. W. H. G.

Potassium Metabisulphite.—J. M. Eder (Phot. Corresp., **25**, 416, from *Journ. Soc. Chem. Ind.*). Potassium metabisulphite (K_2SO_3, SO_2) is used in place of sodium-hydrogen-sulphite to preserve pyrogallol solutions. It is prepared by saturating a solution of potassium carbonate with sulphurous anhydride and adding alcohol. The salt separates as a white crystalline powder and is washed with alcohol.

Citric Acid in Cow's Milk.—F. Soxhlet (*Bied. Centr.*, **17**, 787–788). G. T. Haekel has confirmed the existence of citric acid, as calcic citrate, in normal milk. The examination of many samples shows the presence of about 0·1 per cent. citric acid. A good cow yields daily, therefore, as much citric acid as is contained in two or three lemons. S. C. H.

Report on the Chemical Constitution of Natural Gas.—F. C. Phillips. (From the *Official Report of the Geological Survey of Pennsylvania*). A number of samples of gas taken from various borings in the oil region consisted essentially of hydrocarbons of the paraffin series, with about nine to fifteen per cent. nitrogen.

Carbon dioxide was present in all the samples in small quantities (fractions of one per cent.), and ammonia, oxygen, sulphuretted hydrogen and hydrogen were found in traces in some instances.

Of the hydrocarbons, methane predominates; numbers of unsaturated series are entirely absent.

One hundred cubic feet of the gas was found to have a heating effect, varying with the different samples, equivalent to from seven to nearly nine pounds of pure charcoal. S. C. H.

The Absorption of Gases by Petroleum.—S. Gniewosz and A. Walfisez. *Zeitsch. f. Phys. Chem.*, **1**, 70. (From the *Journ. Soc. Chem. Ind.*) The coëfficient for the absorption of oxygen and many other gases by

petroleum is much higher than that for water. The authors consider it, therefore, illusory to try to protect liquids from oxidation by covering them with a layer of petroleum.

CONSTITUENTS OF SUGAR CANE.—Winter. (*Zeitsch. f. Zuckerind*, 1888, 780. The author states that levulose is not present in normal ripe sugar cane, and that the leaves, while containing cane sugar and glucose, are also free from levulose. Hence, he concludes that the assumption that cane sugar is formed by the condensation of levulose with glucose is no longer tenable. Other constituents of the cane were also examined. S. C. H.

THE PLASTERING OF WINE IN FRANCE.—Report of the United States Commercial Agent, at Limoges. *Board of Trade Journal*, 1888, 439. The addition of sulphate of lime to wine is known as "plastering." It is said that by this means the fermentation is increased, rendered more rapid and complete, and that the wine, while improved in color, has its keeping properties enhanced. Acid sulphate of potash is thus virtually substituted for the bitartrate of potash. Free sulphuric acid is formed in wines which have been plastered. The Academy of Medicine, at Paris, is now discussing whether the practice is desirable, and what effects the changes induced by the sulphate of lime on the mineral constituents of wine are likely to have upon the health of the consumer. S. C. H.

ON THE OCCURRENCE OF BORIC ACID IN WINE.—Georg Baumert, *Berichte*, **21**, 3,290. The author confirms the observations of Ripper & Soltsien with regard to the occurrence of boric acid in the leaves and wood of the vine; and like these chemists insists that boric acid must in future be regarded as one of the normal constituents of the ash of wine. A large number of wines from San Francisco, Spain, France and Germany were examined. S. C. H.

ON PYRODINE, A NEW ANTIPYRETIC.—J. Dreschfeld. *Medical Chron.*, **9**, 89–99. From the *Journ. of Soc. Chem. Ind.* The active ingredient of pyrodine is acetyl-phenyl-hydrazine C_6H_5,N_2H_2,C_2H_3O. It is a white almost tasteless, crystalline substance, possessing more powerful antipyretic properties than either antipyrine, antifebrine or phenacetine. Dose, two to four grains for children; eight to twelve for adults. It should not, as a rule, be given oftener than once in eighteen to twenty-four hours, on account of its toxic properties, but as the temperature is kept low for a longer period than by the use of other substances this is very rarely necessary. S. C. H.

CORRESPONDENCE.

To the Committee on Publications.

GENTLEMEN:—Having observed, in a communication to the *Photographic News*, a criticism of certain claims which I made in a paper read before the FRANKLIN INSTITUTE, in November last [JOURNAL OF THE FRANKLIN INSTITUTE, January, p. 54], I addressed the following reply to the editor of that journal, and would like to have the same published also in the JOURNAL OF THE FRANKLIN INSTITUTE. F. E. IVES.

Mr. C. H. Bothamley, in the *Photographic News*, January 11th, says: "Recently Ives has described a process of heliochromy, of which he says, 'I claimed for this process that unlike any similar process yet suggested, it was based upon a true conception of the nature of light and color-vision, and was a strictly scientific method of accomplishing the object sought after.' Now, as a matter of fact, a strictly scientific process of the same character was described by Dr. Vogel, in 1885. Moreover, Vogel's process does not differ very greatly from the later process of Ives."

By this time, I am well used to having my original inventions and discoveries claimed for others, but I am surprised that so intelligent a writer as Mr. Bothamley should have failed to see at once that there is a very, very great difference between Dr. Vogel's process and my own. It is even somewhat amusing to know that while some are professing not to be able to see any essential difference between my principle and that of Hauron, others may be equally unable to see the difference between it and one that calls for the production of more than twice as many negatives, and in no way, even remotely, suggests my plan of representing most of the primary spectrum colors by color mixtures. I am sure a comparison of the three methods must make it evident to any unprejudiced person that each one is vitally different from either of the others.

Hauron's principle, as nearly as I have been able get at it, was simply that of making sets of heliochromic negatives by exposing sensitive plates through "orange, green and violet glasses," and from these negatives, prints in blue, red and yellow pigments, superimposed on a white surface. Although no approved theory of the nature of light and color-vision warrants such an assumption, Hauron assumed that this method should produce pictures correctly reproducing the light and shade and color of the objects photographed.

Dr. Vogel's principle is stated by Mr. Bothamley, in the *Photographic News*, September 9, 1887, as follows: "Vogel proposes to make a much larger number of images, and to use sensitizers corresponding with every region of the spectrum—for example, napthol blue for red, cyanine for orange, eosine for yellow, safranine for green, and fluorescein for bluish green, the ordinary sensitiveness of the plate being sufficient for blue and violet. In taking the negatives the intensity of the blue and violet must be

reduced by means of a yellow screen. The fragmentary images thus obtained are transferred to stones, and each is printed in a color complementary to that part of the spectrum to which the particular plate was sensitive. This complementary color is found, however, in the dye which is used to sensitize the plate." Mr. Bothamley adds, "it is obvious that the greater the number of spectrum regions represented by separate images in this way, the more accurate will be the reproduction of the different shades and variations of color." In short, Dr. Vogel's principle really calls for a different negative and print for each primary spectrum color, of which there may be said to be either seven or a thousand, although even at the least estimate, which is quite unscientific, the number is already so great as to make the process absolutely unworkable wherever it is necessary to expose all the plates simultaneously, as in landscape photography. It is also certain that no known color-sensitizers will sensitize bromide of silver for such narrow bands of the spectrum exclusively. The process is not scientific, because it is impossible. My own method is perfectly distinct from Hauron's, in that I do not expose sensitive plates through "orange, green and violet glasses," and from Vogel's, in that I do not make separate negatives for each region of the spectrum, but only three, and in such a manner as to secure curves of intensity which correspond to the action of the light rays upon the sets of nerve fibrils which produce color-sensation. This, in fact, is my principle, which is undoubtedly new and true, and is carried out by exposing color-sensitive plates through compound color-screens, which have been adjusted by experiment in photographing the spectrum itself, until they yield negatives having curves of intensity like the curves of a diagram correctly representing the action of the spectrum upon the sets of nerve fibrils in the eye. A knowledge of the true nature of light and color-vision makes it evident that there is no theoretical requirement for more than three negatives, with which accurately to reproduce the color effect of every part of the spectrum, and of every natural color, provided that these negatives are made according to this principle.

BOOK NOTICES.

ANNUAL REPORT OF THE CHIEF OF THE BUREAU OF STEAM ENGINEERING FOR THE YEAR 1888. Government Printing Office, Washington. 1888. pp. 101. 10 plates.

The annual report of Engineer-in-Chief George W. Melville, U.S.N., is one of the most interesting sent out from the Bureau of Steam Engineering for a number of years. The general work of the Bureau is first treated of, showing briefly the work done at the different navy yards and on board each vessel in the naval service. A statement is made of the repairs and work necessary to keep the ships efficient, and of what will be of considerable interest to the public generally, the condition of the machinery for the new vessels. The details of all changes of designs authorized are made matters of public record. Each navy yard is taken up, and a recommendation is

made for the purchase of the machine tools necessary to equip the various shops for the proper handling of heavy work. The questions relating to personnel are presented in such a way, that the necessity for an increase in the engineer force to fulfil the requirements of the new navy cannot be denied. The necessity of properly training enlisted men to perform the duties of the fire room, under the new conditions of forced draft, is strongly set forth, as well as the need of first-class mechanics as machinists, boiler-makers, etc.

It is when it speaks of the experimental work carried on by the Bureau, that the value of the report will be most clearly recognized by the general engineering public. The subjects of the reports of experimental work cover a considerable range, and when it is remembered that they were made by officers temporarily taken from other work, the results show how great an amount of valuable data can be obtained at little expense under efficient direction.

The Chief of Bureau recommends that an experimental board of engineers be appointed to make investigations looking to the increase of efficiency of naval machinery of all kinds. It is to be hoped that this recommendation will be speedily carried out.

While the reports themselves can not be dealt with here, the following list of subjects will show that they are well worth reading:

The Belleville Boiler of the Steam Yacht *Shearwater*.

Tests of an Old and a New Type Herreshoff Boiler.

The Hohenstein Engine and Steam Generator (Naphtha).

Boiler Tests of the U. S. S. *Swatara* (forced draft).

The Trials, with Petroleum as a Fuel, of the Burner of the Petroleum Fuel and Motor Company, fitted to a Locomotive.

Tests of a Thompson and a Tabor Indicator.

Comparative Tests of "Magnolia" Metal and "A" White Brass (Anti-friction Metals).

Tests of Aluminium and Navy Bronzes.

Tests of Navy Bronze and Bronze made by the De-oxidized Metal Company.

H. W. S.

TWENTY YEARS WITH THE INDICATOR. By Thos. Pray, Jr. New York: John Wiley & Sons.

This is an eminently practical work, written by a thoroughly practical man on a subject he fully understands, and is in every way adapted to the wants and understanding of those to whom it is addressed.

It is fully and correctly illustrated, and clearly explains every point in language easily understood by working engineers, carefully avoiding the display of formulas which often obstruct the understanding of other works on the same subject, when read by those not learned in such mysteries, for mysteries they appear to be when out of the hands of men not schooled in the higher academies and colleges.

The examples cited and explained in detail impart a kind of instruction to be had in no other way, and the precautions against mistake, which are a

most important part of the knowledge required to realize the proper information and correct inferences therefrom in using the steam-engine indicator, give it a value that does not appear in any other publication on the subject. Every steam-engine user can profit by its perusal. No person with an extended experience among practical engineers in the use of indicators can fail to realize that it is the work of an author, not only completely conversant with his subject, but also happy in adapting his explanations to the capacity of the readers whom it will most benefit.

Some additional valuable information and recipes are added, and a tabulated showing of areas and diameters of circles, which are useful for reference in computing diagrams. It might probably be improved for the use of many, if a table of multipliers to find the horse-power of piston duty per pound average or mean pressure were added, similar to that published by Paul Stillman, of the Novelty Works, about thirty years since, in which from reference to a side column of diameters of cylinders, combined with a head-line of piston speeds per minute, the intersections showed a ready multiplier for ascertaining the horse-power for each pound of average piston pressure.

Whilst there are many that would not care for this, there are more who could use it with satisfaction and time saving.

It is due to Mr. Pray to say that his publications on this subject have had great influence in producing the growing appreciation of the steam-engine indicator as a valuable and reliable means of detecting imperfections in the construction and working of steam engines, and in suggesting remedies and opportunities for economy, and this is mainly due to the clear and familiar explanation and understanding of the subject he has imparted to practical engineers and mechanics; in short, it is a work that commends itself to them upon simple inspection as the best extant on the subject.

S. L. W.

THE PRINCIPLES OF THERMODYNAMICS. By Robert Röntgen. Translated by A. Jay Du Bois, Ph.D. Second edition. New York: John Wiley & Sons. 1888. pp. xx and 707.

This second edition is much more satisfactory than the first, for several reasons. In the first place, the attempt to teach thermodynamics, without the aid of calculus, is extremely difficult for the teacher and generally unsatisfactory to the pupil. The present edition contains sufficient calculus to give one a good idea of the general principles underlying the subject. The first edition contained practically none. Another improvement is the addition of the English units. The French system is still retained and the formulæ for English units are also given. The labor of changing quantities from one set of units, to use in a formula whose constants are in another set, makes almost any work of this kind written in French units useless for quick work, and the trouble is only taken a few times and the book is then thrown aside.

Writers often do not realize that books that are to be used as reference books for engineers must be written in the units that the engineer uses, and these are feet and pounds in this country.

There is one other improvement to be noted, and that is the comparatively small number of typographical errors. The first edition was full of mistakes; this one has very few.

The book is divided into two parts. The first part treats of general principles and of hot-air and gas engines. The second part treats of steam and steam engines. The first six chapters in each part will give one a fair idea of the general theory of the subject and can be grasped without any great mental effort. A little calculus even here would save a good many pages of plodding, and to the general body of students would be more satisfactory, and there are very few who would take up a volume of this kind to study it who had not some idea of calculus.

In the first part of the work, immediately following the preliminary chapter is a discussion of the Ericcson hot-air engine, the hot-air engines of Laubereau and Lehman and the gas engines of Otto and Laugen. This part of the work is the same as in the first edition, and is, to a certain extent, ancient history. The indicator is described in the introduction, and the addition of indicator diagrams to the work on the gas engine especially would have made it clearer. A discussion of the gas engines usually found in this country would have been of great value for matters of reference. The naphtha and petroleum engines and ice machines might well have been included in the same part of the work and would have added immensely to its value.

The corresponding portion of the second part treats of surface and jet condensers, areas of safety valves and the injector. One chapter and an appendix is devoted to superheated steam and is all that could be desired. Two chapters are devoted to discussing the more important principles which should govern the construction of the steam engine and to making a set of calculations for the same.

The introduction, consisting of two lectures by Prof. Verdet with notes, occupies ninety-seven pages, which, as the translator says, forms an admirable summary of the whole field, but might well have been omitted. A student could not read them with profit, and the general engineer would not.

The examples for practice which occur at the end of each division of the work, have been increased in number, but the answers given to quite a number of them are incorrect. Tables for saturated steam are given, and for the vapors of ether, acetone, chloroform, chloride of carbon, and bisulphide of carbon.

Taken as a whole, the work is one of the best of its kind in English, and should be in the library of every one desiring a thorough knowledge of the subject. As a reference book it is now in fair shape, the only objection being that it is too large a work for one not a student to read, understand, and be able to use with facility. H. W. S.

MODERN HELIOGRAPHIC PROCESSES. By Ernst Lietze, M.E. New York: D. Van Nostrand Company. 1888. $3.

This is probably the only work on photography in the English language, which is adapted to the special use of engineers, architects and draughts-

men, who may wish to employ light for copying drawings, engravings and manuscripts. More than thirty processes are given, with specimen prints by eight of them, employing chloride of silver, citrate of iron, bichromate of potash and nitrate of uranium as the sensitive salts. Two chapters are devoted to printing frames and devices and machinery for sensitizing the paper, and one to a table of the chemicals employed, giving their French and German names, molecular weights and molecular formulæ, composition, price and remarks relating to their properties and preparation. The author has tested most of the formulæ which he gives, and fairly states the advantages and disadvantages of the different kinds of processes. The book admirably fulfils its purpose. F. E. I.

SCIENTIFIC NOTES AND COMMENTS.

ENGINEERING.

THE CINCINNATI-COVINGTON RAILWAY BRIDGE.—The long span bridge over the Ohio between Cincinnati and Covington which was opened on Christmas day, 1888, is another of the many triumphs secured by the Phœnix Bridge Company, under difficult circumstances, and shows the great resources and energy of this well-known firm.

In the face of three severe freshets, which caused rises in the Ohio of from twenty-five to twenty-seven feet above the ordinary stage, the company succeeded in erecting this great bridge of nearly a mile in length and weighing about 10,000 tons, in a little more than nine months. The longest span is 550 feet in length by 84 feet in depth at the centre. The adjacent spans are each 490 feet, and these three river spans, with the approaches, make an aggregate of 4,811 feet. During the erection of the Covington span in July and August, the staging was forced down stream about one foot by a flood. On August 26th, the channel span, of which about 700,000 pounds were in place, with its falseworks, was carried away by a large raft of drift. Within four days the work of replacing it was begun, and in five weeks' time the entire staging, two travellers and 1,200 lineal feet of pile protection, were in place, with the iron and steel floor again on the falseworks.

The entire span was rebuilt and erected by October 28th, or nine weeks after work was commenced. Just before the coupling of the last panel, another severe storm raised the water twenty-seven feet, preventing the immediate completion of the north span until December 9th, when the floor work was run out and the entire span, 490 feet long, was coupled up on December 25th, making sixteen working days. But, in this case, by the use of electric lights, the work was prosecuted by night as well as by day.

The Kinzua viaduct, erected by this same company, was regarded at the time as a very remarkable instance of rapid construction, but it is eclipsed by the Cincinnati bridge, both in time and difficulties.* H.

* Abstract from *Engineering News* of January 12, 1889.

Is "Deep Water Assured" at Galveston?—The Chief of Engineers in reply to an inquiry from Congressman Crain, of Texas, as to the defects of the existing methods of making appropriations for rivers and harbors, and as to the cost of the projected improvements at Galveston and other Texas points, says:

"The Board of Engineers, to which the subject of the improvement of the entrance to Galveston harbor was referred, in a report dated January 21, 1886, estimated the cost of jetties completed to the thirty-foot depth of water outside at $7,000,000, their aggregate length being 54,000 feet. The estimated cost of the jetties out to the crest of the bar, $3,000,000, and that this amount would probably give two-thirds of the depths that jetties carried out to the thirty-foot curves would give. These estimates suppose that the money would be supplied as fast as needed, but, in the opinion of the Board, the depth which the jetties will maintain cannot be stated with precision. The case differs widely from that of the South Pass of the Mississippi, where the scouring current results from the overflow of a large river. At Galveston, before the water can flow out (to produce scour) the tidal basin must be filled from the sea, and the area of the inflow is materially affected by the necessary contraction caused by the construction of the jetties. For this reason the problem is somewhat indeterminate, and it is impossible to foretell with exactness the depth which can be obtained with the works that were projected."

This opinion is a strong confirmation of the position stated in the article on "Jetties for Improving Estuaries," published in the Journal of last April, in which it was said that "Every construction on the bar becomes more or less of an obstruction to the tidal ingress, and consequently neither high jetties nor submerged jetties will satisfy the conditions." Reference was also made to the universal experience with jetties, even where the range of tide is great and ample provision is made for sluicing the relatively short channels, at low water, with unsatisfactory results. In view of these facts, and the uncertainty which our own authorities express as to the probable results, does it not seem unjustifiable and unnecessary to expend so large a sum of money for an experiment which all similar precedents indicate must result in failure?

The best and latest foreign practice in such cases, is not to attempt to remove the bar, or to cut a channel through it, but to construct an outer harbor or a landing pier.

The jetty already built at Galveston has done considerable injury, and a large portion of the present half-million appropriation is being expended in protection work. Thus, the engineer in charge says: "We are extending the jetty-work toward the city. The east end of the island is only two or three feet above mean high tide, and is not an effective barrier between the waters of the gulf and bay.

"It is overflowed at every unusually high tide, and deep channels are cut through it during every storm. If this were allowed to remain as it is now, the completion of the jetty-work would retard the exit of the water from the bay, and would eventually lead to the opening of a permanent channel

between the bay and gulf through the east end of the island. In order to prevent this we are extending the jetty * * * along the bay side of the island," etc.*

Thus it is seen that the large bank of sand collected by the single jetty is so great an obstruction to the efflux of the tide as to threaten to cut a new channel between the jetty and the city, and to abandon its present outlet. The same causes would operate to retard the *influx* of the tide were both jetties completed, but to a much greater degree, and the harbor would become useless, unless maintained by dredging. H.

Some Facts Concerning the Poughkeepsie Bridge over the Hudson.†—The informal opening of this magnificent bridge, on December 29, 1888, by the passage of a train load of the officials, suggests that a summary of this difficult work should be entered upon the pages of the Journal.

The Legislature of New York passed a bill, in 1871, authorizing its construction, without piers.

Capt. Eads and others advised that a span of 2,600 feet was inexpedient, and the plan was modified to include four piers, not less than 500 feet apart in the clear.

In 1873, the Pennsylvania Railroad Company subscribed $1,100,000, being a controlling interest in the capital, which was $2,000,000. On December 17, 1873, the corner-stone was laid, but it was not until 1876 that the work was actually begun under contract with the American Bridge Company, of Chicago. Three piers were partially built by 1878, when work was again suspended until 1886. At this date the Union Bridge Company undertook the contract to complete the entire structure, and began work in September. The original 525 feet rectangular truss spans were modified by the interpolation of the alternate cantilever spans of 530 feet each.

The total length between anchorages is 3,093 feet 9 inches, and with the approaches 6,767 feet 3 inches. The charter fixed the headway at 130 feet above high water, making the grade of track 212 feet in elevation.

Excavation for piers were begun October 8, 1886.

The bottom for more than 100 feet below high water was found to consist of mud, clay and fine sand, succeeded by coarse sand and gravel to rock at 140 feet depth. "The general design of the pier is a crib and grillage, extending from the gravel to ten feet below high water; on this rests the masonry to thirty feet above," and then a steel tower, 100 feet high, to pedestals of trusses. The cribs are 60 x 100 feet in plan and about 100 feet in height. H.

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* *Galveston Daily News*, Friday, October 19, 1888.

† Condensed from the account, by John F. O'Rourke, as published in the *Transactions Am. Soc. of Civil Engs.* June, 1888.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Abbott, Helen C. DeS. and Henry Trimble. On the Occurrence of Solid Hydrocarbons in Plants. From Prof. Henry Trimble.

Academy of Natural Sciences, Philadelphia. By-Laws of the Biological and Microscopical Section. From the Section.

Board of Electrical Control for the City of New York. Second Report.
One copy from The Board.
One from Mr. S. S. Wheeler.

Buffalo Historical Society.
Buffalo Fifty Years Ago.
Geology of Buffalo.
Life and Public Services of Oliver Forward.
Proceedings, January 11, 1871.
Roswell William Hoskins.
The Erie Canal. From the Society.

Bureau of Education, U. S. Circular of Information, Nos. 1 and 5, 1888.
From the Bureau.

California State Mining Bureau. Annual Reports of the State Mineralogist, 1885 and 1886. From the Bureau.

California Surveyor-General Reports, 1882–84, 1884–86, 1887–88.
From the Surveyor-General.

Chicago Department of Public Instruction. Annual Reports, 1872 to 1887.
From the Department.

Chicago Public Library. Annual Reports, 1884 to 1888.
From the Library.

Cincinnati Health Department. Annual Reports, 1880, 1881 and 1886.
From the Department.

Cincinnati Public Library. Annual Report of the Librarian and Treasurer for 1888. From the Librarian.

Colorado State Board of Agriculture. Report of the Secretary, 1886.
From the Board.

Connecticut Agricultural Experiment Station. Annual Report for 1888. Part 1.
From the Station.

Danielsonville, Conn. Annual Reports of the Warden, Chief Engineer and Treasurer for the years ending April 1, 1886, 1887, 1888.
From the Borough.

Darling, C. W. New Amsterdam, New Orange, New York.
From the Author.

Department of Agriculture, U. S. Report of the Commissioner for 1888.
Division of Entomology. Periodical Bulletin, No. 6. From the Dep't.

Department of State, U. S. Reports from the Consuls, July and August 1888.
Trade of Great Britain with the United States, 1791. From the Department.

Elisha Mitchell Scientific Society Journal. Fifth year. Part 2. 1888.
From the Society.

Engineers' Society of Western Pennsylvania. Paper of November 20, 1888.
From the Society.

Halifax, N. S. Annual Reports, 1884-85 to 1886-87.
From the City Clerk.

Harvard College Observatory. Forty-third Annual Report of the Director.
Searle, A. Atmospheric Economy of Solar Radiation. From Prof. E. C. Pickering.

House of Representatives, U. S. Report of Hearings before the House Committee on Agriculture. Adulterated and Compound Lard.
From Dr. Robert Grimshaw.

Hydrographic Office, U. S. Pilot Chart of the North Atlantic Ocean. January, 1889. From the Philadelphia Office.

Illinois Geological Survey. Vol. 7. 1883. From the Survey.

Imperial University of Japan. Calendar, 1888–89.
Journal of the College of Science. Vol. 2. Part 4.
From the University.

Indiana. Second Annual Report of the State Board of Health.
From the Board.

Indiana. Superintendent of Public Instruction. Reports, 3d to 5th, 7th, 8th, 10th, 14th, 16th, 20th, 23d and 28th. From the Superintendent.

Institution of Civil Engineers. Ireland. Transactions. Vol. 18.
From the Institution.

Iowa State Historical Society. 1st to 4th, 6th, 11th to 13th Reports.
Biennial Report of the Board of Curators. 1885.
From the Society.

Kansas State Board of Health. Annual Reports. 1885 and 1886.
From the Board.

Kentucky Geological Survey. Comparative views of the composition of the soils, etc.
Annual Report of the Inspector of Mines.
Notes on Coal and Iron Ores.
Preliminary Report on the Geology of Morgan, etc., Counties.
Preliminary Report on Coal Fields.
Reports on the Geology of Bath and Fleming Counties, Clark and Montgomery Counties, Marion County, Spencer and Nelson Counties, Elliott County.
Reports A, A_2, A^3, B, C, D and F.
Reports of Progress of the Survey. 1886 and 1887.
From the Survey.

Kentucky Inspector of Mines. Annual Report. 1884 to 1887.
From the Inspector.

Landreth, Olin H. Economical Production of Charcoal for Blast Furnace Purposes. From the Author.

Lewiston, Me. Annual Reports of the School Committee. 1888.
Annual Reports of Receipts and Expenditures. 1884, 1885, 1886, 1887, 1888.
Charter Amendments, Ordinances, etc.
Rules and Regulations of the Police Department.
From the City Clerk.

Maine Board of Agriculture. Annual Reports. 1886–87, 1887–88.
From the Board.

Maryland Board of Health. Biennial Report. 1888. From the Board.

Massachusetts Board of Railroad Commissioners. Fifth Annual Report.
From the Commissioner.

Massachusetts Bureau of Statistics of Labor. Report. 1873.
From the Bureau.

Massachusetts. House Documents. 1879 to 1888.
Senate Documents. 1879 to 1888.
Manual for the General Court. 1882 to 1884, 1886 to 1888.
Census Reports. Vol. I. Part 1, and Vol. 3.
Railroad Report. 1863, 1865 to 1867, 1874, 1876, 1877, part 2, 1880, 1883 to 1887.
Election Sermons. 1880 to 1883.
Registration Report. 1887.
From the Secretary of State.

Massachusetts State Library. Reports of the Librarian. 1882 and 1883.
Third and Fourth Annual Supplements to the General Catalogue.
From the Librarian.

Mays, Thos. J. Pulmonary Consumption. From the Author.

Mercantile Library of New York. Bulletin of New Books, No. 11.
From the Library.

Meteorological Council. London. Meteorological Observations at Stations of the Second Order for 1884. From the Council.

Michigan State Board of Health. Abstract of Proceedings. July, 1888.
Restriction and Prevention of Diphtheria.
Restriction of Scarlet Fever.
Prevention of Typhoid Fever.
From the Board.

Michigan Association of County Agents. Proceedings of Annual Conferences. 1883 to 1887. From the Board of Corrections.

Michigan Board of State Auditors. Annual Reports. 1866 to 1886.
From the Board.

Michigan Bureau of Labor and Industrial Statistics. Annual Report. 1886 and 1888. From the Bureau.

Michigan. Charities and Corrections. 1878–79.
Biennial Report of the State Board of Corrections and Charities. 1885–86. From the Board.

Michigan Commissioner of Railroads. Annual Reports. 1878, 1880, 1885 to 1888. From the Commissioner.

Michigan Mines and Mineral Statistics. 1886–87.
From the Commissioner of Mineral Statistics.

Michigan. Farm Statistics, 1884–85, 1885–86.
Joint Documents, 1843, 1844, 1849, 1851, 1852, 1854, 1855 to 1857, 1884 to 1886.
Legislative Manual, 1883, 1885 and 1888.
Registration Reports, 1884, 1885, 1886.
School for the Blind. Biennial Report for 1885.
State Prison Annual Reports, 1878 and 1884.
From the Secretary of State.

Minnesota. Historical Society. Biennial Report, 1889.
From the Society.

Missouri Railroad Commissioners. Annual Report for 1887.
From the Commissioner.

New Hampshire. Board of Health, 1882, 1884, 1886, 1887 and 1888.
Annual Reports relating to Births, Marriages, 1885 and 1886.
From the Board.

New Jersey Agricultural Experiment Station. Annual Report, 1887. Bulletin 34 to 39, 41 to 43, 46 to 49. From the Station.

New Jersey Riparian Commissioners. Reports, 1869, 1870, 1871, 1875, 1877, 1879, 1881 to 1887. From the State Librarian.

Newport, R. I. Annual Reports of the School Committee, 1884–85 to 1887–88.
From the Superintendent of Schools.

Newton, Mass. Annual Report of the City Engineer, 1883 to 1887.
From the Engineer.

New York Almanac for 1888. From Mr. S. H. Needles.

New York City. Department of Public Parks, 1872 and 1873.
From the Department.

New York City. Department of Public Works. Quarterly Reports, December, 1880, December, 1881, 1882, 1883, March, June, September, 1884, March, September, December, 1885, June, 1888. From the Department.

New York State Census, 1865. From the Secretary of State.

New York State Board of Health. Annual Reports, 1885–1888.
From the Board.

New York State Library. Annual Reports, 1887, 1888.
First Supplement to the Subject Index of the General Library. From the Librarian.

North Carolina. Annual Reports of the Agricultural Experiment Station, 1879 to 1883.
Coal and Iron Counties.
Ores of North Carolina.
Report on Waters.
Report on Coal Fields.
From the Department of Agriculture.

New York State Land Survey. Report on the progress of.
From the Superintendent of Survey.
New York State Lunatic Asylum. Reports for 1886 and 1887.
From the Asylum.
New York State. Superintendent of Public Works. Annual Report on Canals, 1887. From the Superintendent.
Ohio. Agriculture Experiment Station. Bulletin No. 2 and 3. 1888.
From the Station.
Commissioner of Railroads and Telegraphs. Report, 1887.
From the Commissioner.
Executive Documents, 1841 to 1880, incomplete.
From the Secretary of State.
Geological Survey Report. Vol. 6.
From the State Geologist.
Railway Report, 1883, 1884, 1886.
State Board of Agriculture. Annual Report. 1885.
State Department. Extract from the Report of the Secretary of State. 1887.
Statistics. 1887. From the Secretary of State.
Oneida Historical Society. Proceedings, January, 1889, meeting.
From Gen. C. W. Darling, Secretary.
Philadelphia Board of City Trusts. Report for 1887. From the Board.
Philadelphia Journal of Common Council. 1886 to 1888.
Ordinances. 1886 and 1887. From the Councils.
Philadelphia Electrical Bureau. Report. 1887.
From the Chief of Bureau.
Philadelphia Photographer. 1865 to 1879. From Mr. J. C. Browne.
Photographic World. Vols. 1 and 2. From Mr. J. C. Browne.
Providence, R. I. Annual Reports upon Births, Marriages and Deaths, 1885 to 1887. From the City Registrar.
Rensselaer Society of Engineers. Selected Papers. No. 5. Vol. 1.
From the Society.
Richmond, Va. Annual Report of the Board of Health for 1873.
From the Board.
Sheafer, P. W. Waste of Anthracite in Mining. From the Author.
Siberia. Map of. From the Century Company.
Signal Office, U. S. Daily International Chart. October, 1887.
Summary and Review of International Meteorological Observations. October, 1887. From the Office.
Steam and its Rivals. From Prof. R. H. Thurston.
Steam Boilers. From Pond Engineering Company.
Treasury Department, U. S. Report of the Chief of the Bureau of Statistics on Foreign Commerce for 1888. From the Chief of Bureau.
United States Geological Survey. Useful Minerals of the United States.
From the Survey.
United States Life Saving Service. Report for 1887.
From the Superintendent of Service.
War Department at the Centennial Exposition of the Ohio Valley.
From Capt. A. H. Reisell.

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 16, 1889.*]

HALL OF THE INSTITUTE, PHILADELPHIA, January 16, 1889.

Mr. JOSEPH M. WILSON, President, in the Chair.

Present, 135 members and twenty-six visitors.

The Actuary presented the minutes of the Board of Managers and reported that at the meeting held Wednesday, January 9th, ninety-three persons had been elected to membership.

The following report of the operations of the INSTITUTE, during the year 1888, was presented by the President:

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For the year 1888.)

The Board of Managers of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the INSTITUTE for the year 1888:

MEMBERS.

Membership at the close of 1887,	2,155	
Number of new members elected, who have paid their dues,	104	
		2,259
Lost by death or resignation,	76	
Dropped for non-payment of dues,	102	
		178
Total membership at close of 1888,		2,081

FINANCIAL STATEMENT.

Receipts:

Balance on hand January 1, 1888,		$1,198 49
Contributions of members,	$5,261 00	
Bloomfield H. Moore Fund in trust,	5,000 00	
Legacy B. H. Bartol, New Building Fund,	5,000 00	
Newbold R. Haines, New Building Fund,	5 00	
Certificates of second-class stock,	10 00	
Fund for completion of serials,	150 00	
Interest on investments,	1,593 02	
Cash from sale of Central R. R. of New Jersey Car Trust certificates,	3,000 00	
Cash from other sources,	8,859 65	
		28,878 67
		$30,077 16

Payments :

Committee on Library,	$1,380 32	
Committee on Instruction,	2,189 95	
Maintenance and repairs to building,	1,803 99	
Salaries and wages,	3,942 00	
Insurance,	300 00	
Fund for completion of serials,	1,242 80	
Temporary loan,	1,000 00	
Interest on temporary loan,	152 22	
Other expenditures,	6,648 39	
		$18,659 67
Balance on hand, December 31, 1888,		$11,417 49
Remaining to be paid on temporary loan,		2,000 00

The financial statement makes a better showing than it did last year, on account of the contributions from members being larger—although the deficiency for the year in expenditures over receipts is considerable, notwithstanding the balance on hand shows a little greater at the end of the year than it was at the beginning.

LIBRARY.

The Library has been increased during the year by 3,930 bound and unbound volumes and pamphlets. Under the direction of the Library Committee, a thorough verification of the contents of the Library has been made, which has long been needed. A new system of rules, regulating the use of the Library by non-members, has been put in operation, with satisfactory results. During the year, the Endowment Fund of the Library has been increased by the gift of an additional sum of $5,000 to the Bloomfield H. Moore Memorial Fund, by Mrs. Clara Jessup Bloomfield Moore.

For additional details of the condition and operations of the Library, the members are referred by the Board to the report of the Committee on Library.

THE JOURNAL.

The Board refers to the JOURNAL with satisfaction, since, in addition to maintaining its excellent scientific reputation, it has continued to be self-supporting. The publication of the Index to the first 110 volumes, which was decided upon last year, has been steadily proceeded with, and at the present time is so well advanced that its early completion may be announced. As this work, which is quite onerous, has been voluntarily assumed by the officers of the INSTITUTE, and must be taken up at times when it does not interfere with their regular duties, the delay in its completion will be understood.

The Board would again commend the JOURNAL to the attention of the members and others, as worthy of a more generous support than it receives.

LECTURES.

The smallness of the appropriation made to the Committee on Instruction for lectures during the past year, rendered it necessary to cut down the number

of the lectures, in order to reduce expenses. The Committee has succeeded, however, as heretofore, in securing the services of a number of eminent men to lecture without compensation, and its efforts to maintain the high scientific character of the work done in this field deserve commendation. Many of these lectures, subsequent to their delivery, appeared in the JOURNAL.

During the past year the following lectures were delivered, viz:

January 6.	Dr. C. B. Dudley, *one*, on "Fuel Oil."
January 9.	Prof. C. Hanford Henderson, *one*, on "Aluminium."
January 13.	Commander Allan D. Brown, U.S.N., *one*, on "The Electric Distribution of Time."
January 16.	Mrs. R. H. Richards, *one*, on "Sanitary Science in the Home."
January 20.	Prof. Wm. D. Marks, *one*, on "The Duration of Incandescent Electric Lamps."
January 23.	Prof. Chas. R. Cross, *one*, on "The Determination and History of Musical Pitch."
January 27.	Mr. Everett Hayden, *one*, on "The Pilot Chart of the North Atlantic issued by the U. S. Hydrographic Office."
January 30.	Mr. John E. Sweet, *one*, on "Machine Designing."
February 3.	Hon. Edward Atkinson, *one*, on "The Growth of Manufactures in the United States."
February 6.	Mr. Alex. E. Outerbridge, Jr., *one*, on "The Relation Between the Physical Properties and Chemical Constituents of Cast Iron."
February 10.	Mr. Wm. Kent, M.E., *one*, on "Weighing Machines."
February 13.	Mr. Edward Weston, *one*, on "Electro-Metallurgy."
February 17.	Mr. E. A. Gieseler, *one*, on "Standard Measures."
February 27.	Mr. Fred. E. Ives, *one*, on "Some Recent Advances in Photography."
N'v'mb'r 5.	Prof. Lewis M. Haupt, *one*, on "The Feasibility of Underground Railroads in Philadelphia."
N'v'mb'r 12.	Frank J. Sprague, *one*, on "Long Distance Transmission of Power by Electricity."
N'v'mb'r 19.	Prof. William M. Davis, *one*, on "Some American Contributions to Meteorology."
D'c'mb'r 3.	Dr. Persifor Frazer, *one*, "Introductory to the Course on Chemistry."
D'c'mb'r 17.	Dr. T. Sterry Hunt, *one*, on "Some New Points in Chemical Theory."
D'c'mb'r 27.	A Christmas Lecture for the Children, by Dr. Persifor Frazer.

At the present time, thanks to the liberality of certain interested members, the Committee has been enabled to introduce the feature of a series of illustrated popular lectures on scientific subjects, for the benefit of the employés of the various manufacturing establishments, and of the members of the several trades. These lectures, thus far, have been well attended, and it is hoped will not only prove useful to those for whose benefit they have been arranged,

but will contribute also to the popularization of the educational work of the INSTITUTE.

DRAWING SCHOOL.

The Drawing School continues under the same management, which has brought it into a condition of high efficiency; and the Board expresses its satisfaction with the character of the work done by the director and his assistants.

The attendance during the spring of 1888 was,	203
And for the Autumn Term,	179
Total attendance for the year,	382

These figures exhibit a slight falling off as compared with those of the preceding year; but there is no question that, with increased accommodations in a new and larger building, the size and efficiency of the school can be much augmented.

COMMITTEE ON SCIENCE AND THE ARTS.

The reorganization of this Committee, which was effected in 1887, has proved of substantial benefit, as is demonstrated by the greater efficiency and steady improvement of its work. The Committee, during the past year, has examined and reported upon thirteen applications, and has now thirty-seven cases under consideration. In one case, the Committee awarded the Elliott Cresson Medal, and in six cases recommended to the Board of City Trusts the award of the Scott Legacy Premium and Medal. The Committee issued during the year a circular-letter, calling to the attention of inventors and discoverers the fact that the Committee was empowered to award or to recommend the award of the Cresson and Scott Medals, under the impression that by this means only could the fact be properly brought to the knowledge of many deserving persons. This circular-letter was widely published in the technical and scientific press, and has had the result of bringing many meritorious subjects to the Committee for consideration.

SECTIONS.

The Chemical Section largely increased its membership during the year, and its work exhibits a most gratifying condition of activity.

During the past year, the Electrical Section was disbanded.

STATE WEATHER SERVICE.

The conduct of the business of the State Weather Service was continued during the past year under the general direction of the Committee on Meteorology, and the service is apparently in a satisfactory condition of efficiency. The publications of the Committee appear regularly in the JOURNAL, and its annual report appears in the Annual Report of the Secretary of Internal Affairs of the Commonwealth.

REORGANIZATION AND FUTURE WORK.

A most encouraging feature in the prosperity of the INSTITUTE has been the substantial increase in the number of its members, and the work is still

going on. The move in this direction was started in October, under a resolution appointing a committee for increase in the membership. This Committee is well organized, and great credit is due to the gentlemen who compose it, for the energy and good work they have shown.

A few months after the founding of the INSTITUTE, the membership amounted to over 1,600. Comparing the present size of Philadelphia with what it was at that time, it is very evident that there should be a very much larger membership than the books have shown for some years back. The ease with which the present increase has been made, only shows what can be done with a little exertion. Some of the new members have been particularly active in this work. There are very many who would gladly join us, if the subject were only brought to their attention, and the objects of the INSTITUTE fully explained to them. The annual income from members is what we must depend upon, to keep up the efficiency of the INSTITUTE; and what we want now, is the addition of about 1,000 or 1,500 members. With a little energy and enthusiasm among those now connected with us, it can be done.

The Committee on Reorganization has taken up the question of subscriptions to the Building Fund, and it is hoped that, in a very short time, the arrangements will be perfected, and the work of actively soliciting subscriptions toward this object will go on. In regard to the wants of the INSTITUTE in this direction, what was said in the last report can only be repeated—the great need of room in the present building, the lack of convenience in the educational departments, an increase of space for the Library, protection from fire, and a better location. Increase in membership will produce the wanted annual income; subscriptions to the Building Fund will give the needed buildings.

Meanwhile, the quiet work of the INSTITUTE goes on; merchants, manufacturers, builders and all the trades are profiting by what it does. But, like still waters running deep, it does not make itself conspicuous in this work before the world, and does not receive the substantial encouragement it needs. Perhaps some exertion on the part of its members may accomplish this last

By order of the Board. JOSEPH M. WILSON, *President.*

REPORT OF THE COMMITTEE ON THE LIBRARY.

The Committee on the Library respectfully reports that during the year 1888 there have been added to the library:

Volumes bound,	1,574
Volumes unbound,	563
Pamphlets,	1,431
Total,	3,568
Maps, charts, etc.,	362
Total number of volumes in the Library, December 31, 1888, bound and unbound, as ascertained by a verification of the catalogue, made this year, and exclusive of all pamphlets,	31,762

In addition to the above the Library contains 18,398 pamphlets, of which—

7,796 are arranged in the pamphlet collection,
2,748 are in the memorial library,
4,185 are in the various departments of the Library,
3,996 remain yet unclassified.

The loose maps and charts number	872
Miscellaneous designs and drawings, ...	578
Lithographs and photographs, ...	1,019

The collection of duplicates at the close of 1888, not enumerated in the above, contained

Volumes bound and unbound, ...		2,232
Pamphlets, ...		4,854
Periodicals, ...		5,759
Maps and charts, ...		155
During the year duplicates have been disposed of to the value of, ...	\$167 28	
And books received to the value of, ...	127 95	
Leaving to the credit of the exchange account,	\$39 33	

Serials.—During the year thirty-nine serials have been completed; some of them difficult to obtain, and all of much value to the library.

The addition of \$5,000 to the former gift of \$10,000, by Mrs. Clara J. Moore, constituting the Bloomfield H. Moore Memorial Fund, the interest of which sum is for the use of the Library, will be judiciously used by the Committee in furtherance of the design of the donor. The books purchased with this fund are all appropriately labelled, and a record of the title and cost of each volume made in a book kept for that purpose.

The rules of the Committee requiring non-members of the Institute to receipt for books consulted, was enforced during eleven months of the past year. The number of these receipts filed was 1,449.

Charles Bullock,
Chairman of Committee on the Library.

The Chemical Section submitted the report of its operations during the year, which will be found in the Proceedings of the Section, page 127.

The foregoing reports were severally accepted.

The Secretary presented the following resolution, adopted by the Committee on Science and the Arts, at the stated meeting, held Wednesday December 5, 1888, viz:

Resolved, That the Committee on Science and the Arts, to which was referred the communication of Mr. W. E. Lockwood, respectfully recommends that the Institute shall construct and take charge of the dynamometer and appurtenances for making tests of the quantity of the hammer-

blow of locomotive driving wheels, in accordance with the plans suggested by the joint committee of the American Railway Master Mechanics' Association and the FRANKLIN INSTITUTE, and that the INSTITUTE shall render all the aid in its power to make the said tests and to report upon the same; *provided*, that the INSTITUTE shall not be at any expense in the matter.

The resolution was approved.

Mr. J. C. BAYLES, of New York, gave an oral description of the process and apparatus devised and used in the manufacture of "Spiral Weld Steel Tubes," illustrating his remarks by a view of the machine employed for the purpose and of an exhibition of a specimen of the product. (Mr. BAYLES' remarks will be prepared for publication.)

Mr. S. LLOYD WIEGAND spoke in terms of high praise of the ingenuity of the process, and of the value of the product, and moved the reference of the subject to the Committee on Science and the Arts for investigation. The motion was carried.

Prof. C. HERSCHEL KOYL, of Sharon Hill, Pa., by invitation, made an exhibition, with a full-size model, of the operation of the Parabolic Semaphore invented by him, and which formed the subject of a paper at the stated meeting of the INSTITUTE held in November last.

The Secretary presented his annual report, an abstract of which appears in this impression of the JOURNAL.

The result of the annual election, held this day, resulted in the choice of the following gentlemen:

For *President* (to serve one year), ... JOSEPH M. WILSON.
For *Vice-President* (to serve three years), . . FREDERICK GRAFF.
For *Secretary* (to serve one year), ... WILLIAM H. WAHL.
For *Treasurer* (to serve one year), ... SAMUEL SARTAIN.
For *Auditor* (to serve three years), . . . WILLIAM A. CHEYNEY.

For *Managers* (to serve three years):

GEORGE V. CRESSON,	JOHN LUCAS,
PERSIFOR FRAZER,	SAMUEL P. SADTLER,
EDWIN J. HOUSTON,	WM. H. THORNE,
ENOCH LEWIS,	JOHN J. WEAVER.

For *Members of the Committee on Science and the Arts* (to serve three years):

L. L. CHENEY,	SAMUEL R. MARSHALL,	CHAS. E. RONALDSON,
L. D'AURIA,	WM. MCDEVITT,	SAMUEL SARTAIN,
J. L. GILL, JR.,	J. R. MCFETRIDGE,	CHAS. A. RUTTER,
F. LECLERE,	A. E. OUTERBRIDGE, JR.,	S. LLOYD WIEGAND,
W. B. LE VAN,	GEO. H. PERKINS,	CARL HERING.

Mr. H. R. HEYL offered the following amendments to the By-Laws, which had been duly posted:

PROPOSED AMENDMENTS TO THE BY-LAWS.

ARTICLE IV.—PAYMENTS.

"SECTION 1.—Every member, other than a holder of second-class stock, shall pay an annual contribution of five dollars, but the payment of one hundred dollars within any one year shall constitute a member for life, with an exemption from all annual payments.

"SEC. 2.—All sums of money received from life memberships shall be placed in the Permanent Endowment Fund, the income from which only shall be available for the general purposes of the INSTITUTE.

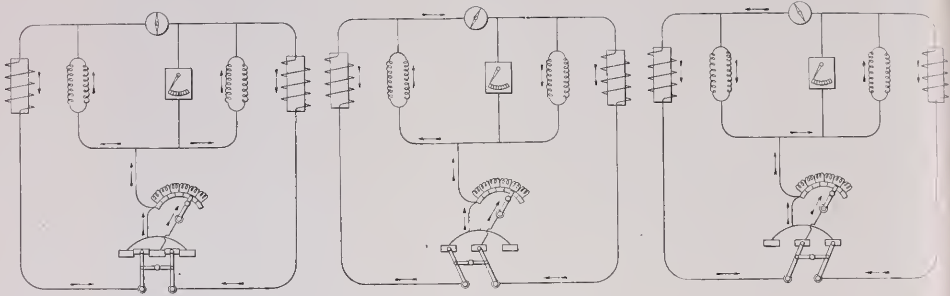
"SEC. 3.—Stock of the second-class may be held in trust for persons not of legal age, and shall be liable to the payment of only one-half the annual fees due upon stock of second-class held by persons of legal age; provided, that when such minors arrive at legal age, new certificates, subject to the full annual contribution, shall issue on payment of the customary fee.

"SEC. 4.—The annual payments of fees for membership shall be due and payable on the 1st of October in each year, in advance; but all members elected after the 31st of January in each year shall pay, in advance, at the rate of *fifty cents* a month to the 1st of October next ensuing."

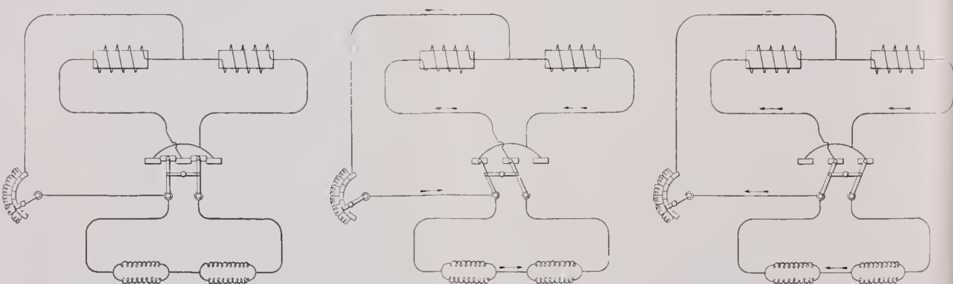
A motion to publish the same in the daily papers was voted down.

Adjourned.

WM. H. WAHL, *Secretary.*



First Diagram—Shunt Machines.



Second Diagram—Series Machines.

JOURNAL

OF THE

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVII. MARCH, 1889. No. 3.

THE TRANSMISSION OF POWER BY ELECTRICITY.

By FRANK J. SPRAGUE.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 12, 1888.*]

The Lecturer was introduced by the Secretary of the INSTITUTE, and spoke as follows:

MR. SPRAGUE: MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

The transmission of power by electricity is now an established fact, and every day, for the ordinary uses of life, its application is rapidly spreading. The principles of its application are well settled. The dynamo and motor have been brought to a remarkably high efficiency and leave little to be desired as converters of energy. The future of the transmission of power from central stations, under ordinary conditions, is a matter of commercial development. The special application of the transmission of energy over

long distances depends chiefly upon the demand which exists for such transmission and the intelligent application of principles already well known. Distance is a relative term. It does not seem a difficult matter to transmit five horse-power ten miles, but a gigantic problem to transmit 1,000 horse-power one mile; the latter appeals to our imagination, and yet the former is, in one sense, the more difficult problem, not so much because of any difference in the general principles involved, as in the fact that in the construction of machines of high electro-motive force we meet with more serious difficulties in the matter of insulation and the element of personal danger to the operator.

It is not my intention to enter into any general discussion of the question, nor to go into the particulars of dynamo and motor construction, for the limits of this paper would not permit this; but I shall briefly point out the different phases which the transmission of power by electricity may assume, show some of the general conditions which must be met, emphasize the practicability of such transmission, and then more particularly discuss a new method for the determination of the elements of a single transmission which my own practice has brought out, and which I have found it advisable to adopt. I shall here consider only the use of a continuous current and a direct transmission.

For the purpose of this paper, we may consider the following cases of transmission:

(1) Transmission from a central station conveniently situated near the centre of a manufacturing district, over an area of from one to 100 square miles, in units varying from a fraction of a horse-power to fifty or 100 horse-power. Such a system is illustrated by the Edison two and three wire circuits in operation in a large number of cities in the United States. Referring to my own work alone, its practicability is illustrated by the fact that in Boston I have nearly 150 motors in operation, in New York about 125, and in New Orleans nearly 100; there being in various stations not less than 1,200 machines, varying from a half to thirty horse-power, and used in no less than 130 different

industries. These machines are operated under potentials, varying from 100 to 440 volts, and are run on constant potential circuits. The maximum distance in this class of work is, at present, about one mile on 220 volt circuit, and the practical limit for this potential from a single station is about four square miles.

In considering how far this Central Station work can be carried, we must bear in mind certain facts; power transmitted means the transference of an energy whose value may be expressed, as in all cases of fluid transmission, by the product of the quantity and pressure—that is, by the product of the electro-motive force and the current. With any given amount of energy transmitted, the electro-motive force and the current will vary inversely. The laws of distribution are clear. With any given work done, loss on the line, electro-motive force at the terminals of the motor, and distribution, the weight of the copper will vary as the square of the distance, its cross section, of course, varying directly as the distance. With the same conditions, the weight will vary inversely as the square of the electro-motive force used at the motor. With the same cross section of conductor, the distance over which a given amount of power can be transmitted will vary as the square of the electro-motive force. If the weight of copper is fixed, with any given amount of power transmitted and given loss in distribution, the distance over which the power can be transmitted will vary directly as the electro-motive force. Hence, if it is practical to economically transmit power one mile under 200 volts pressure—that is, if the investment in copper is not disproportionate—then, by increasing our pressure to 800 volts, we can transmit this power four miles without changing the ratio of the investment. Of course, I am now speaking of the use of a bare wire and assuming that the cost of stringing the four miles of given weight of wire is no more than stringing an equal weight one mile. Of course this is not strictly so. As a matter of fact, however, it is a practical thing to transmit and deliver over an area of 100 square miles, from one central station, under a pressure not exceeding 1,000 volts; and

the larger the amount of power distributed and the greater the number of units, the more cheaply it can be done. The question arises, "Would it be economical, in a district of this character, to deal with the larger horse-powers?" My answer is unquestionably "yes." It is true that the actual efficiency of double conversion would vary from fifty to seventy per cent., depending upon the distance and the pressure used, but experience has developed the fact that not over about thirty-five to forty per cent. of the maximum capacity of all the machines in a circuit represents the average duty demanded; and since this is so, it follows that the amount of power that can be contracted for will at least equal, probably considerably exceed, the steam-power in the central station. I say "steam-power" because in a large majority of cases in this kind of transmission steam and not water will be the prime source of energy. When we consider the economy of operating a large, well-designed and properly constructed steam plant, and the great advantage to the user where the electric motor replaces the ordinary steam engine, it does not need a very shrewd commercial sense to see the advantages of this method. In fact, there is not a city in the United States, no matter how numerous its factories, which could not have them run better than to-day by a well-constructed electrical plant, working under pressures which would not be dangerous to life.

(2) Somewhat analagous to the system we have just discussed is the transmission at constant potential with the motors applied with various loads at constantly varying points. Such a system of transmission is that which exists in the parallel circuit system for railroad work. There are now in the United States alone no less than sixty or seventy electric railways in operation or under construction. The most extensive of these, up to the present writing, is the Richmond Union Passenger Railway, whose characteristics may be cited as an illustration. This has about twelve miles of track and is operated under a pressure of about 450 volts. The central station has a capacity of about 375 horse-power. The farthest point reached is about three and one-

half miles from the station. The equipment consists of forty-one cars, with eighty-two machines whose aggregate normal capacity is between 600 and 700 horse-power, nearly double the steam capacity. The car units develop anywhere from nothing to twenty horse-power. The maximum load which has been put upon the system at one point at any time is the starting of about twenty-two cars about two miles from the station, requiring, probably about 125 to 150 horse-power. This road now having made nearly 600,000 miles, the practicability of this kind of transmission may be accepted as an assured fact.

(3) The transmission from one station to another, at which latter point are a number of independent machines, each of which has a variable load and is required to run at constant speed. An example of this is the transmission from a water-power to a stamp-mill, where the different batteries of stamps are operated by independent machines. The most satisfactory method is to maintain at the receiving station a constant potential, and to use for the receiving machines motors wound to be self-regulating, according to laws which I gave some time since. The dynamos should either be compound wound or the field regulators adapted to increase the electro-motive force of the machine as the load increases. Constancy of prime speed is an essential; or, if it does not exist, then there must be a combined mechanical and electrical governor which will assure a definite electro-motive force, which shall correspond to each variation of the current.

(4) The transmission between two stations as last mentioned, save that the condition of automatic regulation is not essential. In this case the dynamos may be either shunt, compound or series wound, and the motors either shunt, cumulative or series. Such a plant is now running in one of the mines at Aspen, Col. The electro-motive force there used is about 450 volts and the distance somewhere about a mile.

(5) Transmission with a single line over a long distance, with the motors distributed throughout the entire line. This is a case which may occur in some manufacturing dis-

tricts, but is more apt to occur in such work as canal building, dredging or mining in river beds. It can be accomplished by the use of a constant current circuit, using constant current motors, or with the same aggregate electromotive force on a constant potential circuit. A marked case is the mining operations carried on at the Big Bend Tunnel of California, in a large river cañon, where about a dozen machines, developing from five to ten horse-power, are used for operating pumps and derricks, and are supplied by two lines of from 600 to 1,000 volts potential over a distance of about eight miles from the central station.

Thus far I have considered the distribution with a practically constant potential at the motors, and the parallel method of distribution, as distinguished from the constant current method, where the motors are in series. This last for large powers and many machines, is a limited and unnatural method, the former a comprehensive and natural method, which facts are entirely independent of the question of relative electrical potentials or currents, because, on constant potential circuits, we can work at 100, 1,000 or 5,000 volts if we choose.

Among some of the special cases of power transmission I will briefly note the following:

(6) The transmission from one point to another, using two series wound machines, where the motor has a constant torque or a load per turn. The motor being at rest, as the electro-motive force of the generator is raised by increasing its speed, or by increasing the resistance of a shunt around its field with any given speed, the current, which may be expressed by

$$\frac{E}{K}$$

will increase until the torque is great enough to start the motor against its load, when the current will become stationary. A motor electro-motive force being now created, the current is expressed by

$$\frac{E' - e}{K} = \frac{E}{K}.$$

Any increase of the electro-motive force of the generator

will be followed by an equal increment in the motor electro-motive force, the difference between the two, and hence the current, remaining perfectly constant. The speed of the motor being known for one electro-motive force and load, its speed for any other electro-motive force may be determined, and fast or slow hoisting be regulated entirely at the generating station.

(7) The transmission to one point from another, with a single generator and a single motor with variable loads, presents two solutions. The first is the use of the compound dynamo and differential motor; but a far more interesting solution is the use of two series machines which, when properly proportioned, become perfectly self-regulating. I will briefly touch upon the theory of this method of transmission. We have the condition that the same current passes through each field and armature, and also the condition that the speed is constant, while the work is variable. Since work may be expressed as a product of speed and torque, and since the speed is constant, it follows that the motor torque must vary directly as the work. Again, we have as an expression for the work done the product $e\ C$. Since the speed of the motor is constant, e must vary directly as the strength of the field, which, where the magnetization is low, will vary directly as the current, and when more highly magnetized in a much less degree. E being $E\ .\ m\ .\ f$ of the generator and K the resistance of the circuit, we have—

$$C = \frac{E - e}{K}$$

and, as we have already stated,

$$E \text{ varies as } e, \text{ as } E - e, \text{ as } C$$

and work—

$$\text{varies as } e\ C, \text{ as } C^2, \text{ as } e^2, \text{ as } E^2$$

The dynamo likewise being driven at a constant speed, E likewise varies as the strength of its field. If m equals the number of turns of wire in the dynamo field, and n those in the motor field, then the ampère turns or magnetizing forces are expressed by $m\ C$ and $n\ C$. It follows from what

proceeds that the magnetizations due to $m\,C$ and $n\,C$ should vary in the same proportion; in other words, the characteristics of the generator and the motor must be similar between the limits of the variation in load. Should the machines used be improperly proportioned, then the regulation can be largely determined by putting a resistance in the line circuit, or shunting one or other of the fields with a resistance. The electrical efficiency of the circuit being

$$\frac{e}{E},$$

we have the following fact: That the electrical efficiency is a constant for all loads with the limit of automatic regulation. If the machines are of the same general type, then, when correctly proportioned, the ratio of their weights and watt capacities should be the same as the electrical efficiencies of the circuit.

(8) As a modification of the proceeding, especially where large powers, long distances and necessarily high potentials are used, it is advisable to divide the generators and motors into a battery of machines of indentically the same weight and character, the number of the machines being the ratio of the electrical efficiencies, the generators all to be driven from the same line of shafting, and the motors to drive on to a common line, and the current to pass through all the machines in series. This I consider the only sound method when dealing with large powers and high potentials and single units of generation and recovery, especially where automatic regulation is required. Its advantages are manifest. One of the greatest difficulties which we have in dynamo-electric construction in closed-circuit machines, especially where using the drum system of winding, is the difficulty of securing perfect insulation when high potentials are used.

One thousand or 1,200 volts seem as high as it is now advisable to go in machines of this type, where currents of any magnitude are to be used. In the transmission of electricity reliability is an essential, and a potential of 3,000 or 4,000 volts, distributed over three or four machines in series,

is, despite the increased number of machines, far less liable to cause failure than where put into one machine of the aggregate size of the four ; and in the event of the breaking down of one machine, the units may be so proportioned that by a corresponding change in the units at the other station, or a proper variation of the regulating shunt to the fields, it becomes quite possible to continue automatic operation. As an illustration of this distribution of machines, if wishing to use dynamos and motors of an electrical efficiency of about ninety-five per cent, a commercial efficiency each of about ninety per cent., and with about sixty per cent. as the total commercial efficiency of the circuit, I would, with a distance of about nine miles, use five series machines identical in construction, each wound for about 1,200 volts, three of which machines would be driven by a common line of shafting at the generating station, and two driving on to a common line of shafting at the receiving station. It will be noticed that both in the single and multiple unit series system, the electro-motive force and the current vary equally. I hope at an early date to be able to show this last system in practical operation.

The indirect methods of transmission, such as through a secondary battery of generators, motor generators, and secondary batteries, I will not here discuss.

I come now to the consideration of some new, interesting and very practical formulæ for determining the elements of a single transmission of a given amount of power. Before entering upon its discussion, it is necessary to state why I differ somewhat from the methods which have hitherto been published.

Those who have followed with any particular interest the progress of the development of the transmission of power by electricity, must be more or less familiar with the early experiments of Deprez and the papers by Prof. Lodge and Mr. Gisbert Kapp. The experiments of Deprez have not had that practical result which had been hoped for them, and it seems to me as if an attempt had been made to go further than commercial demands warrant. We must avoid the consideration of the subject from a purely

theoretical light. *No system of transmitted energy can be made profitable unless the cost of the same at the far end, including not only the actual cost of production but the capitalized value of the possibility of accident due to the fact that the prime source of energy is not under immediate control, shall be less for the transmitted energy than the price that would have to be paid for its production there by water, steam, or some other agency.* As attractive as the use of water-power appears as a prime source of energy, its uses are very limited, and every year will become more and more so; and unquestionably the great future of the transmission of power by electricity will depend upon the fact that in a large proportion of cases it will be cheaper to carry energy in the shape of electricity on a wire by the shortest cut between two points than to pack it up in the shape of wood or coal on the back of a mule or behind a horse. I have no sympathy with the theoretically possible, but really impracticable consideration of the transmission of power, from Niagara to New York; for Niagara has a far greater value as a sublime spectacle than as a commercial factor in metropolitan affairs. I will then in my estimates confine myself to that which is practical and possible, and will consider the conditions under which power shall be so transmitted. Messrs. Lodge and Kapp have deduced some very interesting formulæ, but one of the conditions which was taken into account by them was that of leakage. In a purely theoretical study this is as it should be; but the transmission of power by electricity to meet the demands of actual life must above all things be reliable; and by this I mean, not merely certain to supply power at the end of the line, but to deliver a definite percentage under perfect regulation and a known cost. This cannot be done with the uncertain and variable element of an unknown but material leakage; for if this leakage exists, then it must be a variable quantity depending not only upon the condition of weather but likewise upon the continual variation which exists in the electro-motive force when the load is not constant. We meet then with the condition that in the successful installation of a plant for the transmission of power, we must be

free from material leakage; that is, the leakage must be so small under all possible conditions of service as to never interfere with the efficiency and reliability of the transmission. Hence in the formula which I in practice adopt to determine the elements of my work, I shall assume a line of practically perfect insulation. I am justified in this because the additional expense to secure this desirable result is more than compensated for by the reliability of the service. We can only accomplish this by the most careful line erection and choice of insulators. It can be materially aided by running the positive and negative leads each on an independent line of poles and perfectly clear of all trees, and of course a well-covered wire can be used. When a double line of poles is used, it is advisable to wrap the lower ends with bare wire for a distance of about six feet above the ground, and to connect these bases together; or, if the poles are close together, a galvanized iron or copper wire should be taken around each pole at the distance given and joined together. This is to avoid the possibility of a serious shock in wet weather, which might be received by a person leaning against a wet pole if any accident should occur to the line insulators when very high potentials are used.

In the formulæ which are given, I shall make use of the term "couple efficiency." As long ago as the spring of 1888 Drs. John and Edward Hopkinson made tests of efficiency of double conversion with the Edison-Hopkinson and Manchester dynamos, the efficiency of the former rising at times to over eighty-seven per cent., and of the latter to nearly seventy-eight per cent. No others have made so thorough an analysis of the action of dynamo-electric machinery, and my own experience warrants me in assuming, for the purpose of this paper, a commercial efficiency of double conversion, where two machines are connected by a metallic circuit of no appreciable resistance, or what I have called the "couple efficiency," of not less than eighty per cent., which is only allowing about ninety per cent. commercial efficiency for the dynamos and motors. It will oftentimes rise higher than this, but I think it advisable in a specific formula to

adopt a perfectly safe figure. This couple efficiency for either single, shunt, or series machines, or nests of machines, is easily determined with considerable accuracy and small expenditure of power. The method I prefer was one independently proposed but similar to that first put into practice by Dr. John Hopkinson, that English scientific investigator to whom we all owe so much. It may be termed the variable differential method; and depends upon the use of an electro-mechanical couple. The first diagram illustrates the testing of two shunt-wound machines. Two such machines are belted to a common line of counter-shafting having three pulleys, each being given its proper speed. To the third pulley is connected a motor of about one-third the capacity of one of the machines to be tested, this motor being one of a perfectly well-known commercial efficiency, and provided with means for varying its speed; or, if desired, the power can be transmitted through a good dynamometer. The like terminals of the large motors are then connected together, an ampère meter put into this circuit, and a potential galvanometer connected across the terminals. One terminal of each field is likewise connected to its proper line, and the other terminals of these fields are brought to the movable levers of a two-way circuit changing switch. One contact is carried to the main line, and between it and the other two is inserted a variable resistance, which in the middle position of the switch is short circuited. We have, then, the two large motors connected in an electro-mechanical couple, and to the same shafting is connected a third motor. The main dynamo being started, the switch set in the middle position, the motor is speeded up, which sets the counter-shafting in operation and drives both the machines as dynamos, each exciting its own field. If the machines are symmetrical, no current whatsoever will pass over the branch connecting the two; they are simply in the position of two dynamos in parallel circuit with each other, with no external circuit and no path over which the current can flow except that through their field magnets; consequently, very little power, save that of friction, is taken. The switch being

moved in one direction, the resistance is thrown into the field of one machine. The electro-motive force which it develops at this particular speed is now reduced; it becomes a motor, and current will flow over the connecting mains from the other machine, which is still a dynamo, which current is roughly expressed by the quotient of the difference of the electro-motive forces of the two machines, divided by the resistance of the circuit. By varying the resistance in the fields this current can be made of any value up to the limit. We have here, then, one machine acting as a motor, and driving on to the counter-shafting with a certain number of horse-power, this counter-shafting driving the other machine as a dynamo with a certain greater amount of horse-power, this second machine furnishing the current which operates the first as a motor. The deficit, or loss of efficiency between the two machines and the friction is supplied by the third. By reversing the switch the resistance is first cut out of one field, and then thrown into the field of the other machine. This machine now becomes a motor, and the other machine becomes a dynamo. This reversal is not instantaneous, because it takes time for the field magnets to charge and discharge. The ampère metre will drop to zero, and will then rise again progressively.

This method of testing can be used for two purposes, one for testing the actual horse-power developed and the couple efficiency, which can be done by measuring the current, the electro-motive force between the machines and the horse-power delivered to the shafting by the third motor, and for the other purpose of testing simply the heating capacity of the armature coils with a given number of ampères. For this latter purpose it does not matter practically whether the machines are run at their normal speed and generate their normal electro-motive force, or whether some lower electro-motive force is used. If a lower electro-motive force is present, it simply means that there must be a greater ratio of difference between the field magnet strengths and a larger resistance used with the reversing switch.

When desiring to test the two series machines, the con-

nections are somewhat different, and are illustrated in the second diagram; the machines, of course, being mechanically connected as in the first instance. We can similarly test a multiple unit series system; and in all these cases, by the introduction of an artificial resistance into line, we can produce all the phenomena of an actual long-distance transmission. This method of testing, where there can be an immediate variable and controllable reversibility of the dynamo and motor, and test of the efficiency of transmission under widely varying conditions, illustrates in one of the most beautiful ways the flexibility and utility of electric transmission.

Assuming then, that we have no leakage, and that our dynamos and motors have a definite known efficiency, we will take up the consideration of a few formulæ.

Let l = distance between the generating and receiving stations in feet, plus the sag.

n = number of effective horse-power to be delivered on the motor shaft.

E = electro-motive force at the terminals of the motor.

v = number of volts fall of potential on the line.

$E + v$, or E', being, of course, the electro-motive force at the beginning of the line or the terminals of the generator.

a = efficiency of the motor.

CM = circular mils of conductor.

An electrical horse-power is 746 watts, watts being the product of current by electro-motive force. Then for any horse-power n, a motor efficiency of a and an e. m. f. of E at the motor terminals, we have the number of ampères equal to—

$$\frac{746\ n}{E\ a} \tag{1}$$

Allowing m ohms as the resistance per mil-foot of copper, the total line resistance would be

$$\frac{2\ m\ l}{C\ M}$$

for a complete metallic circuit. From the above we have for

the drop or fall of potential on the line,

$$v = \frac{746\,n}{E\,a} \times \frac{2\,m\,l}{C\,M} = \frac{1492\,n\,m\,l}{E\,a\,C\,M}$$

or

$$C\,M = \frac{1492\,n\,m\,l}{E\,v\,a}, \tag{2}$$

Substituting for m its approximate value, 10·5,

$$C\,M = \frac{15666\,n\,l}{E\,v\,a}$$

Let me give a practical illustration. Suppose we have a motor, the efficiency of which is ninety per cent at 400 volts electro-motive force and when developing ten horse-power, and that we wish to transmit this ten horse-power 5,000 feet from a station and elect to lose about nine per cent on the line.

Our initial electro-motive force will be 440 volts, and we would have,

$$C\,M = \frac{15666 \times 10 \times 5000}{400 \times 40 \times \cdot 90} = 54396$$

which is about equal to a No. 4 B. W. G.

Again, suppose we wish to transmit five horse-power over a distance of one mile on a complete metallic circuit of 45,000 cm., allowing five per cent. increase of length for sag, and no leakage. Suppose further, that the initial line potential be 300 volts, and that we wish to have 250 volts at the motor terminals, it is required to find the commercial efficiency which the motor must have.

Transposing our formula we have,

$$a = \frac{15666\,n\,l}{E\,v\,C\,M}$$

and substituting,

$$a = \frac{15666 \times 5 \times 5544}{250 \times 50 \times 45000} = 76\%$$

This formula is useful in determining what we cannot as well as what we can do. For example, if we made the

condition ten horse-power, all others remaining the same, the commercial efficiency of the motor would have come out 152 per cent., a most excellent machine indeed, and yet it is precisely this absurd thing that people practically say they will do in many of the statements which are made in relation to this subject. No science admits of more easy determination of conditions by plain and simple laws, and none brooks less violation of them.

(*To be continued.*)

SOME AMERICAN CONTRIBUTIONS TO METEOROLOGY.

By Prof. Wm. M. Davis, of Harvard College.

[*A Lecture delivered before the* Franklin Institute, *November 19, 1888.*]

(*Concluded from Vol. cxxvii, page 115.*)

As Espy's synopsis represents the more mature form of his theories, it is taken as the source of most of the following quotations, rather than the earlier papers, in which many of his statements are exaggerated. His *Fourth Meteorological Report* (1857), also contains much of value, and furnishes entertaining as well as instructive reading.

In the first place, he attempted to establish by experiment how great a degree of cooling there would be in consequence of the expansion of an ascending mass of air, and concluded that it would be about one degree and a quarter for every hundred yards of ascent; later determinations show that it is somewhat too small, the value now accepted being about one-fifth greater. This rate of cooling will prevail till the dew-point is reached.

The formula still often given to ascertain the height at which the dew-point is gained, or at which the base of cumulus clouds will stand, on the assumption that they are formed in uprising currents or air from the earth's surface,

is: height = complement of dew-point × 300 feet. I must plead guilty to having aided in giving currency to this error, but my regret thereat has been lessened by seeing that Professor Ferrel has made the same statement in his *Recent Advances.* The mistake would have been advoided if Espy's advice had been followed about weighing the contents of his synopsis carefully; for he there clearly explained that the dew-point of the ascending column will not be reached when the air has cooled down to the dew-point that it had at the ground; "for the vapor itself grows thinner, and the dew-point falls about one-quarter of a degree for every hundred yards of ascent."

He goes on to say: "As soon as cloud begins to form, the caloric of elasticity of the vapor or steam is given out into the air in contact with the little particles of water formed by the condensation of the vapor. This will prevent the air in its further progress upward, from cooling so fast as it did up to the point." When the dew-point is 70°, the rate of cooling after condensation begins is reduced to five-eighths of a degree for an ascent of 300 feet; if the dew-point is higher, the cooling is a little less; if lower, a little more. "It follows that when the cloud is of great perpendicular height above its base, its top must be much warmer than the atmosphere at that height, and consequently much lighter." When hail or snow is formed, the caloric of fluidity given out will still further retard the cooling.

Espy is perfectly right, when judged by the subsequent progress of meteorology, in claiming much for this theory; its value may be seen from its continual use in modern essays and text-books; it may be added that very few of the modern text-books present the case more clearly than Espy did in his synopsis, except that his old-fashioned terminology is, of course, exchanged for one more consonant with the mechanical theory of heat.

The course of regular diurnal phenomena dependent on changes of temperature is given in masterly form by Espy. "Clouds will more frequently begin to form in the morning, increase in number as the heat increases, and cease altogether in the evening, when the surface of the earth becomes

cold by radiation. The commencement of the up-moving columns in the morning will be attended with an increase of winds, and its force will increase with the increasing columns, both keeping pace with the increasing temperature. This increase of wind is produced partly by the rush of air on all sides at the surface of the earth toward the centre of the ascending columns, producing fitful breezes; and partly by the depression of the air all around the ascending columns, bringing down with it the motion which it has above, which is known to be greater than that which the air has in contact with the asperities of the earth's surface." This is the original explanation of the diurnal increase in the velocity of the wind, which has since been rediscovered independently by Köppen.

An essential corollary of the theory, fully understood by Espy, was that descending currents would be warmed by compression, at the same rate as ascending currents are cooled by expansion; hence, as the Committee of the French Academy—Arago, Pouillet and Babinet—reported on Espy's theories in 1841: "We should not hereafter adduce in the mean state of the atmosphere a descending current as a cause of cold," for, however cold the air may be aloft, it will be heated by compression in descent, so that on reaching the ground it would have high and not low temperature. The origin of thunder-storms by the descent of cold air from above into warm air below is objected to and with good reason, for in such case, the storm cloud would be hollow, forming only where the descending current might cause condensation in the air that it entered. The mass of the descending current itself could not by any possibility become cloudy. But ascending currents must be cloudy after a moderate ascent, unless very dry when rising from the ground; and as ascent continues, the cloud becomes heavier and may yield rain. Thus did Espy's theory furnish a simple and effective process to explain the general conditions of atmospheric condensation; yet, even to the present time, the process suggested in the last century by Hutton is quoted, if not accepted, by most text-books, though it can be shown on good physical grounds to be altogether

insignificant in its effects. Hutton thought that if two masses of air, both saturated but of unlike temperatures, were mixed, condensation would result, because the temperature of the mixture would be below its dew point. This is perfectly true. But the process fails to explain the facts, chiefly because it does not occur. It is a rare thing to find adjacent masses of air of unlike temperatures and both saturated. It is almost impossible for them to mix in the intimate way required by Hutton, except to a very small extent. And even if they should mix in large volume, the amount of rain produced would not be as much as that which falls, on any admissible assumption as to the masses of air concerned. Although so defective, Hutton's theory is still quoted extensively, and Espy's simple theory that clouds and rain result from the mechanical cooling of ascending currents of air, is relatively neglected. Where clouds and rain occur, there the air ascends; and its ascent is due to its instability.

Espy thus explained the rainy belt around the equator, not by saying as is still so common and so incorrect that the moist, warm and light surface air rises into the cool air above, thereby implying that the lower air is cooled by the cold of the upper air; but because the warm, light air cools as it rises and so condenses its vapor spontaneously. In the same way, winds that are constrained to rise as they flow over mountain ranges, become cloudy and give forth rain, not because they are cooled by the cold of the high mountain, but because they are cooled as a consequence of the work that they do in expanding during ascent. They would be rainy even if the mountain were warm. Conversely, cloudy currents descending from mountain passes become clear, not because they enter the warm lower air, but because they are warmed by compression in descent. A consequence of the passage of moist winds over mountains is seen to be not only the excess of rain on the windward slope, but also the occurrence of warm, dry winds at the foot of the leeward slope; and thus a rational explanation was early given for the winds of the Foehn or Chinook kind. (See "A History of the Foehn in *Mountain Meteorology*" by W. M. D., Appalachia, iv, 1886, 344).

Perhaps the most striking illustration of Espy's deductive method is seen in the explanation that he gave to the clear space in the centre of tropical storms, known as the "eye of the storm." Clouds being the product of ascending currents clear air must indicate the pressure of descending currents; hence, in the centre of the general ascending and cloudy winds of the storm there must be a descending and hence clear current. This curious suggestion is in Espy's *Fourth Meteorological Report*, where my attention was called to it by Mr. H. H. Clayton: as in the case of diurnal increase of wind velocity, Espy's explanation of the clear eye of the storm has been repeated independently by Köppen a few years ago. Espy even advocated the artificial production of rain in time of drought by making large fires to excite vertical convectional currents, and his works include some extraordinary examples of showers thus produced. A certain correspondent wrote him that one summer day he ascended Monadnock, a fine isolated mountain in southwestern New Hampshire. The sky was cloudless; away on the low ground, a farmer had set fire to his waste brush, and the smoke rose high in a straight column; at last a cloud formed over it, the cloud grew, and soon gave forth a shower of rain, moving away from its point of beginning as it entered the upper wind. Not another cloud appeared. Other curious examples of artificial rain are given, and some of them are so remarkable that we must wonder at the little consideration they now receive.

But Espy, like Redfield, found in storms the chief problem of meteorology. Dove, then the leading meteorologist of Europe, supplied with numerous tabular records of temperature, rainfall, and other climatic elements from the old observatories of the continent, became chiefly a statistical meteorologist. Redfield and Espy, in a new country where old records were rare, devoted their attention to actual processes, not to numerical averages. Redfield approached the problem, as we have seen, purely from the inductive, observational side, without many preconceptions; Espy approached it with his mind pretty well made up as to the processes involved and with strong preconceptions in

favor of the theory by which the processes were explained. Redfield found that storm winds whirl around in essentially circular paths about a centre of low pressure, and he attributed the low pressure to the centrifugal force of the whirl. Espy said that storms are essentially examples of convectional circulation, that the central low pressure must be their cause and not their effect; and that the winds must flow radially inward to the place where the pressure is lowest, causing clouds and rain by ascent there. Each one supported his views by numerous examples, and as the truth lay really between them, each one was right to a certain extent. Redfield drew most of his examples from storms at sea, recorded in the logs of vessels, and it is not a little curious that the fuller material now in our possession shows conclusively that it is precisely in marine storms that the winds are most nearly circular, as Redfield maintained. Espy took his examples, when he got so far as to appeal to the facts, from land storms almost exclusively, and the more radial course now known to characterize the land winds gave some color to his theory of radial indraft. He utilized, first with the assistance of this INSTITUTE, and afterwards under Government aid, the records from many volunteer observers, and gathered a large number of observations of high value. His conclusions were that storms sweep across our country from west to east; that they possess a medial axis of low pressure, generally extending north and south, with the central minimum on the middle of the axis; and that the winds flow toward the axis from either side, with a tendency toward the centre. The much fuller and more accurate records of our Signal Service, show that in a general way this is true, for our storms have prevailingly an elongated area of low pressure; but the winds undoubtedly circulate spirally around the centre, and do not flow radially toward it.

Our two great students differed, I may say quarrelled, on this point. Each one was persuaded that he was right; but to their differences of opinion I do not care to give emphasis. It is more profitable to study the points on

which they were right than to magnify their errors and differences. Yet in this matter of the circulation of the winds in storms, one cannot help dwelling on their disagreement, and all the more because it would have been avoided if they had taken heed of an extraordinary little article "On the Rotary Action of Storms," that appeared in the *American Journal of Science* in 1843, at the height of their discussion. Charles Tracy, then a young graduate of Yale College, who had a taste for mathematics, said to himself, if we may reconstruct his mental revery, these eminent men are both in a sense right. Espy is right in maintaining that the tendency of the wind in storms is centripetal, because the primary cause of the movement is the low pressure at the centre of the storm; and Redfield is right in insisting that winds have an essential whirling movement, because the rotation of the earth will inevitably cause such a whirl in any system of centripetal winds. In this simple explanation, the true value of the deflective effect of the earth's rotation was for the first time applied in meteorology. The effect of the earth's rotation on the cause of the winds was first suggested by Hadley in 1735; but this explanation, although still commonly current, is wrong in implying that the earth's rotation affects only the meridional component of a body's motion, and that it alters the velocity of motion. Tracy, unconsciously following certain mathematicians, stated the problem correctly, and was the first to apply it in its true value to the winds. It matters not in what direction a body moves, it is deflected to the right of its course in this hemisphere, and to the left in the other; the force of the deflection increasing with the sine of the latitude.

Tracy recognized that if an original impulse were the cause of the rotary movement of a storm, "the forces of the whirlwind would be rapidly exhausted, and its existence must speedily cease. A stable source of momentum, adapted to originate and sustain the rotary movement, is still required; and it is now proposed to develop such a source of momentum in the forces generated by the earth's diurnal rotation." It is admitted that Espy had established "a

qualified central tendency of the air, in both the general storms and the smaller tornadoes," and then, acting on this beginning, the deflective force arising from the earth's rotation is called on "to cause and maintain a whirlwind." * * "Upon the same principle the tornado, the typhoon and the wide-spread storm of the Atlantic, if their currents move toward a central spot, must have a rotary character. * * In every such case, the incoming air must be regarded as a succession of rings taken off the surrounding atmosphere and moving slowly at first but swifter as they proceed toward the centre. Each such ring is affected by the law of deviation during its passage. * * * and hence the ring begins to revolve when far from the centre, turns more and more as it draws near it, and finally as it gathers about the central spot all its forces are resolved into a simple whirl. * * * In the southern hemisphere, the same law of deflection produces contrary results." It is clearly shown that the deflective force is independent of the direction of motion, but varies with the sine of the latitude. "The necessary condition, centripetal motion, may arise whenever a central spot subjected to intense heat is surrounded by a cool atmosphere. * * * The destructive storms of our sea-coast may have such an origin among the eastern islands of the West Indies, from which they appear to proceed."

There are few scientific essays that outrank this one for clearness and originality of statement. As already said, it contains the first application of the correctly defined deflective force to meteorological questions, and clearly anticipates some of Ferrel's original and independent work of several years later date. Although it was followed by no other study in our science, I think Tracy's name deserves fully as eminent mention among American meteorologists as is accorded to Hadley among the English. Early in 1883, I had the pleasure of meeting Mr. Tracy, just after having as it were resurrected his early paper of forty years before. He said he had often wondered why attention had not been given to it, quietly adding, "I have never been able to see that it was incorrect." It is to be regretted that so original a mind was diverted entirely from a study in which we must think it would have labored to great advantage.

Our next American, Ferrel, is certainly the greatest meteorologist native to America, if not the greatest of the world, if we judge of his rank by the advance that he has given to the science. To no other man do we owe so much in the way of large, broad and as is now generally conceded correct views of atmospheric phenomena. As Espy had deductively applied physical principles to meteorological problems, so Ferrel applied mathematical methods to their solution, and greatly to their benefit, not only in the results immediately secured, but in the indication that he gave of a new line of inquiry open to the meteorologist of the future. His contributions from first to last cover the whole field of mathematical and physical meteorology, electricity excepted.

Ferrel's explanation of the general planetary circulation of the winds is one of his greatest discoveries. It has certainly advanced farther toward the truth than any other theory ever suggested. It may be indicated by the following considerations.

The first general view of atmospheric circulation over the earth as a whole, calls for convectional interchange of air currents between equator and poles. An overflow of warm expanded light air takes place from the equatorial belt, and a return current of cold heavy air comes back from the poles. Under this simple view, there would be only north and south winds, and we should find low pressure around the equator where the overflow takes place, and high pressure about the poles, whence the under return current comes. But the winds blow obliquely, and the polar regions are characterized by low pressure, not by high pressure. Herein lies one of the great meteorological puzzles that remained unsolved until Ferrel approached it. Theory seems to be wrong, but in truth, as Ferrel showed, it is not wrong but only incomplete. The text-books give no sufficient, explanation of the facts. Buchan, the leading meteorologist of Great Britain, had but a lame explanation of it to offer: he attributed the south polar low pressure to the "presence of an excessive amount of moisture in the atmosphere." The belts of high pressure around the tropics are also insufficiently explained by most writers: they are

regarded as the effect of the crowding of the equilateral overflow as it advances along the converging meridians toward the poles; but if this were true, surely the highest pressure should be at the poles, where the meridians converge fastest.

Ferrel's explanation is vastly better. He shows that as the winds run toward the poles, they are deflected by the earth's rotation into oblique courses, and hence a great polar whirl results, turning in the same direction as the cyclonic storms, and reversing the high pressure that would be caused by differences of temperature alone into a low pressure, by the action of centrifugal force. The air thus held away from the poles is seen accumulated in the tropical belts of high pressure. (The share that Alex. Thompson, of Edinburgh, had in this discovery is referred to in *Science*, 1887.) The case is so simple that it seems like an exaggeration to proclaim it as a great discovery; but great discoveries have a way of seeming very simple after they are made.

I have spoken of this at length, because it has a direct bearing on the theory of storms. Mention has already been made of Dove's disagreement with Redfield as to the whirling character of our ordinary bad weather storms: Dove believed that the alternation of our southerly wet winds and northerly cold and dry winds was not the effect of the passage of rotary storms as Redfield had explained it, but simply the interplay of the equatorial and polar currents of the general planetary circulation: he thought that the return polar current was northerly or northwesterly in this hemisphere, about opposite the southwesterly equatorial current. This is mechanically impossible, as Ferrel has shown, and his explanation of storms as the conflict of planetary winds falls to the ground when it is seen that our return polar current is a northwesterly wind, gradually running obliquely out of the polar whirl below, while the equatorial overflow current as gradually enters it above. The polar current cannot be of itself a northeast wind until it reaches the trade wind belt; but if some cause arise, locally more powerful than the planetary gradients,

the latter may be as locally overcome, and a new wind will be the result; it is this new local wind that Dove had identified with the polar component of the general circulation, but which we must regard, in the light of Ferrel's results, as a distinct interruption in it. I give importance to this difference because Dove's view has been largely accepted, and has its followers to this day.

The comparison that Ferrel instituted between the general, permanent circulation of the atmosphere over a hemisphere of the earth and the local, temporary circulation in a cyclone is one of the broadest views that has yet been presented to the meteorological student. A cyclone is an area of warm or moist and hence light air, which therefore becomes locally the centre of a vertical convectional circulation. The rotation of the earth requires that the vertical circulation shall be compounded with a rotary circulation; and the centripetal forces thus produced cause a further decrease of pressure at the centre. The spiral inflow below is accelerated by gravity, and gains energy as it advances; but the spiral outflow above has to run against the gradients, and thus expends the energy gained below. In the polar whirls, the central air is cold and heavy, and the high pressure that would be thus produced is reversed to a low pressure by the whirling; here the convectional circulation is downward at the centre, the spiral inflow aloft is accelerated, and the spiral outflow below has to run against the gradients; it is a cyclone with a cold centre. In both, the air withheld from the centre is seen in a surrounding ring of high pressure.

An important application of this is found in the study of anti-cyclones. These are generally treated as if they were independent meteorological individuals, like cyclones, but with the circulation reversed; descending instead of ascending at the centre; but Ferrel's demonstration shows that if such were the case, the distinguishing mark of anti-cyclones, their central high pressure, would be reversed to low pressure, as it is at the cold poles of the planetary whirls; the areas of high pressure that are so common on our weather maps are therefore regarded as in part the effect

of the continental distribution of pressure, and in greater part as the effect of the overlapping of the high pressure rings of two or more adjacent cyclones.

Ferrel's theory of tornado action is as original as those already given. It has no rival: unlike all others, it accounts not only for the quality of the tornado whirl, but for the quantity of its blast as well; it gives a rational explanation of the marvellous concentration of energy in the tornado centre. It is impossible to do justice to it in a brief abstract; the reader should consult the original essays in which, if the mathematical treatment is difficult to follow, the explanatory chapters are at least open to any diligent student. Indeed, if the meteorologists of the country were more familiar with Ferrel's writings it would be greatly to our advantage, for although so well grounded, his theories have received little general recognition. This is probably in part because his essays—especially their mathematical portions—require close reading; but it is in greater part the result of inconspicuous publication, and the habit of teachers and readers in general to stop at text-books and compilations instead of going to original papers. Ferrel's first essay appeared in the *Nashville Journal of Medicine and Surgery* in 1856, and his second was in *Runkle's Mathematical Monthly* (Cambridge, Mass.) a few years later. Neither of these journals gave any popular currency to Ferrel's ideas. In 1861 and in later years, several articles were published in the same *American Journal of Science*, in which most of Redfield's contributions had come out, and all of these have been republished in the professional papers of the Signal Service; so that now there is less excuse than formerly for neglect of these fundamental contributions. In 1878 and subsequently, the more elaborate *Meteorological Essays* were published by the Coast Survey "for the use of the Coast Pilot;" a neat little sarcasm, the pilot must have thought, for in most part they are intelligible only to the mathematically-elect; but the pages that compare theory with fact are fine reading and deserve to be much better known than they are. Finally the *Recent Advances of Meteorology* was published as an appendix to the Chief Signal Officer's reports for 1886; and

at present it is gratifying to learn that Professor Ferrel is preparing a popular book in which his theories will be presented in form for the general student.

The laborious analysis of wind records from all parts of the world made by Coffin serve admirably as tests of Ferrel's theories. An essay on "The Winds of the Northern Hemisphere" appeared in the sixth volume of the *Smithsonian Contributions* in 1852, and over twenty years later the twentieth volume of the same publication contained the final tables and charts for the world, which are the most extensive yet published. These were completed after Coffin's death by his son, and are accompanied by a general discussion from the competent hand of the Russian meteorologist, Woeikoff. Although the nature of most of the records made it impossible to discuss the velocity of the wind, and therefore its direction only was considered, still even though thus incomplete, these charts are yet the best source of information for a great part of the world. The general circulation of the wind thus determined gives satisfactory confirmation of Ferrel's theories; but as only surface winds are considered, the field is by no means yet exhausted: observations of upper clouds and on high mountains in various parts of the globe are still greatly desired. All this deserves much more extended mention than can be given it here; I have time only for the following reference to storms, which but seldom come under Coffin's special attention. He wrote in 1853, that the irregular motions of the wind are best accounted for "by supposing that in the general current of the atmosphere, there are occasional eddies ('cyclones'), in which the air revolves spirally from right to left in the northern hemisphere, and from left to right in the southern, the curve making an angle with radius vector equal to that which the mean direction of the wind makes with the maximum and minimum line of the barometer, and that the barometer falls in the forward half of these eddies and rises in the latter half, the amount of rise and fall diminishing as we recede from the central axis on either side * * * Now,

it is remarkable that this is the very manner in which the best observations show it [the air] to move in the region of storms, during which it is known that our greatest barometric changes are apt to occur; and our discussion seems to prove that the two great American champions of the law of storms, with those who have followed the one or the other of them on the other side of the water, are both right. The attention of one being chiefly directed to the evidence of rotary motion, he failed to make prominent the inward tendency, though I am aware he has even admitted the probability of its existence, while the other, laboring to establish the latter motion, omitted the former" (*Amer. Assoc. Proc.*, 1853, 89, 91). This is an inductive confirmation of the deduction that Tracy had given ten years before.

The veteran American meteorologist of our time remains to be mentioned. Professor Loomis of Yale College has for fifty years been one of our leaders, and to his text-book of meteorology most of us who have any knowledge of the science turn as our first introduction to it. His first articles followed Redfield's first by but few years, and in 1843, when he was studying out with great labor the scattered records of a land storm, it appears that he was not satisfied with either Redfield's circles or Espy's radii, for in all storms he saw "certain common characteristics, namely, an inward motion with a tendency to circulate against the sun."* It is significant to find the centripetal motion mentioned here before the circular. This same paper closes with a most interesting suggestion concerning the results that would be gained from a year's series of two daily meteorological charts of the United States. We must all congratulate the venerable author on having not only lived to see the accomplishment of this early desire, but on working successfully in his advanced age on our weather charts, and producing from them the finest inductive statement concerning the physical peculiarities of cyclonic storms that has yet been published. Just as Coffin's work affords inductive

* *Trans. Amer. Phil. Soc.*, ix, 1846, 181.

foundation for Ferrel's theories of the planetary circulation, so Loomis's results give safe ground for Ferrel's theoretical views of cyclonic circulation. These investigators have followed very different paths, and in the agreement of their conclusions we find the best confirmation of the correctness of the modern physical views of our science.

From the numerous precise statistical statements that Loomis has presented, I quote a few that will illustrate not only the value but the character of his purely inductive method: indeed, for the beginner, there are few examples of inductive research better adapted to place the method before him. The average velocity and course of many storms is taken from the weather maps of the Signal Service; it is twenty-six miles an hour, and directed to N. 81° E. The rain area generally extends eastward about 550 miles. Now divide all the storms into two classes: (1) All the slow storms, whose velocity is less than the average; (2) all the fast storms, whose velocity is greater than the average. Then measure the forward distance of the rain area for all the individuals of the slow class, and take its average; do the same for all the fast storms. It then appears clearly that the rain area extends far ahead of the fast moving storms, and but little ahead of the slow ones; and on the theory of concomitant variations, we must conclude that velocity and rain area are in some way connected, either as common results of some other cause, or as cause and effect. It has been thought that the forward extension of the rain area, itself the effect of some cause yet to be detected with definiteness, is the cause in good part of the fast motion of the storm: but exception has been taken to this view. In the same way, analyze the directions of the storms; the average direction of all that turn more north than the normal average is N. 44° E.; the average direction of the longer axis of the rain area of the same storms is N. 53° E.; the more southerly storms run S. 69° E., and their rain areas average S. 65° E.; here again is a distinct example of concomitant variation, and we must conclude even with more confidence than before that the rain area and the course and velocity of our storms are intimately connected.

So great has been the scientific interest in these studies, which Professor Loomis has now for over ten years presented to the semi-annual meetings of our National Academy of Sciences, that they have been translated abroad, and to them more than to any other source must the inquirer turn for information on this growing subject.

I have intentionally called this lecture a review of "*Some* American Contributions to Meteorology," in order to emphasize the manifest fact that many contributions remain unmentioned. The diligent student will find much instruction and entertainment in completing the review here begun.

November, 1888.

INDUSTRIAL APPLICATIONS OF COTTON-SEED OIL.

By ROBERT GRIMSHAW (Member of the INSTITUTE).

[*Read at the Stated Meeting of the* FRANKLIN INSTITUTE, *December 19, 1888.*]

JOS. M. WILSON, President, in the Chair.

MR. GRIMSHAW:

In these days there is no industry in which the main product should be considered alone; the by-products, what they are and what may be done with them, are very often almost equally important.

Glycerine, pyroligneous acid, and a hundred other important products, have for us an importance far beyond that which was at first claimed for them. The one a waste article, the other at first made only by direct process, we find the waste of yesterday the valuable commodity of to-day, while the manufacture of fine charcoal for gunpowder making, produces pyroligneous and acetic acids which are worth more than the charcoal.

So is the case of the cotton-seed oil (itself formerly a by-product in the manufacture of meal from the cotton seed, this in its earlier turn a cumbersome residue of an important

industry), the question must arise what is left after the oil is expressed; and what may be made from this residuum; what are the substances left in the purification of the oil itself, and what may be done with them?

The uprising of humility is as strongly illustrated in the case of the cotton seed as in the tale of "Cinderella." Long considered a refuse for which there was no use; long burned or thrown away, its main and by-products are now very important elements in our national industries. The garbage of 1800 became the fertilizer of 1870, the cattle food of 1880, and is now made to yield table food and useful articles of industrial pursuits.

To-day we have in the oil the main product; in the residuum after its expression a valuable fertilizer, and the best cattle food; in the hulls, excellent fuel; in the ashes of these hulls, potash of high commercial value, and in the refuse most excellent stock for laundry and toilet soaps.

Cotton oil is used for a great variety of purposes, and probably at the present time it is more widely known throughout the world and used for a greater variety of purposes than any other oil.

In the United States it is made from the decorticated and crushed upland cotton seed, by expression, this process yielding an odorless dark brownish-green oil having a specific gravity of about ·9224. Being then treated with alkaline solutions (generally containing potash or soda), the clear yellow oil, which is odorless and flavorless and has the same specific gravity as the crude, is drawn off by racking, and the residuum, which is called soap stock, is treated in a suitable manner.

The refined oil boils at about 600° F. and congeals at about 50° for summer- and 32° for winter-pressed.

The American seed yields a clearer oil than the Egyptian or the Indian; and that from our sea-coast a darker oil than that from the uplands. The oil made in Great Britain is not so clear as ours, because the seed there treated is Egyptian or Indian, and is not decorticated, owing to the difficulty of picking it; our American cotton parting with its fibre in a more satisfactory manner, and generally yielding

better to treatment. The section of country also has much to do with the quality of the oil, as do also the weather and the season. Some years, owing to more favorable weather, Texas oil will be the best, and others, Tennessee. In some seasons, owing to more favorable weather, the oil obtained from the seed grown in the western sections of the cotton belt, is superior to that grown in the eastern part, while in other years the eastern states yield a better quality of oil.

The present consumption of cotton seed for oil-making purposes is about 800,000 tons a year, from which there are made about 28,000,000 gallons, worth about thirty cents per gallon in the refined condition.

The principal use to which it is put is for food purposes. The well established fact that it is not only healthful, but more easily digested than almost any other article of food, accounts for the rapid increase of its use for culinary purposes, which to-day amounts to a very large proportion of the entire production. It is safe to say that of the 28,000,000 gallons made each year, nine-tenths enter into the composition of food products, principally refined lard and salad and cooking oil. It is also used for illuminating; in the manufacture of nuts and bolts; for wool soap; for soap for laundry, bath and toilet purposes; as an emulsion in medicine, to take the place of olive oil; as a substitate for cod-liver oil; in packing sardines, and for dozens of other purposes as a substitute for olive oil.

Its lubricating properties are poor, as it comes in between the drying and the non-drying oil. This debars its use as a lubricant either for journals or for steam cylinders.

By reason of its non-drying properties it cannot be used as a wood filler; nor for stuffing hides in the manufacture of morocco and other leathers.

As there is nothing which can be added to it to make it "drying," it is for the same reason debarred from use as a menstruum for paints.

It has been used to some extent as a cosmetic, to take the place of vaseline and similar substances. Woollen mill soap made from cotton-seed oil is claimed to be superior to all others, and is now the principal soap used by the

woollen mills of this country, being also extensively employed in England, Scotland and elsewhere. The oil is also used for making laundry and all descriptions of family and fancy soaps.

From the soap stock there is made a washing powder which, although not strictly one of the products of the cotton oil itself, owing its principal virtues to the soda and potash used in the refining process, and which are thus utilized, are nevertheless by-products in the manufacture.

From the seeds, after the oil has been expressed, there is made an oil-cake, which is an excellent food for stock.

The ashes from the hulls are a very good fertilizer for sugar-cane and for root crops, and are so used extensively.

As an illuminant it ranks between sperm, which has the highest illuminating power of all the burning oils, and lard, which is about the next best; there being about twenty-five per cent. difference in the candle-power of sperm and lard oils, while cotton-seed oil comes in about half way between them. Alone, it may be burned in any of the ordinary lamps used in burning either sperm or lard oils. It may be mixed with petroleum in slight proportions to increase its freedom of burning: this requiring some modification of the lamp employed.

There are on the coast of Maine a great many establishments which put up what are known variously as sardines and "shadines," being young shad and herring put up as are the true sardines of Sicily and the south coast of France. All of these are cooked, and most of them put up in boxes, with cotton-seed oil; and of the immense quantity of true sardines put up in France and other European countries, nearly nine-tenths are now done with cotton-seed oil instead of with olive as formerly.

Among other uses for which cotton-seed oil would be likely to be available may be mentioned the manufacture of perfumes as an extractive from flowers, candle making and steel tempering.

But it is perhaps in the manufacture of refined lard that cotton-seed oil finds its principal use. It has been employed for this purpose for about forty years; being at first

employed to temper down stock which was intended for sale to very cold climates and which for that reason required to have its chilling or stiffening point lowered. Its excellence for this purpose being known, and taken in connection with its cleanliness of source and manufacture, and high nutrient powers, its use became more general, and it was used in lard for temperate climates, its extreme fluidity being corrected by the use of a sufficient proportion of pure caul fat of the beef. So popular did this admixture in refined lard become, and the preference soon setting in so strongly in favor of those refined lards containing cotton-seed oil and beef fat in considerable proportion, that at last a lard was prepared especially for the use of Isrealites, whose religion wisely prohibits the use of any product of the hog, and who had for a long time employed pure refined yellow summer cotton-seed oil for salad dressing and for cooking. The filthy and unscrupulous practice of some of the lard packers, in running into the prime lard tanks every portion of the hog, has led many who have no religious scruples against any product of the hog, and who wish for something which should be free from unclean materials or revolting suggestions and associations. A third reason adduced in favor of the cotton-seed oil lard is that it is anti-dyspeptic; while it is claimed that only about three-fifths as much is needed to produce the same results as by hogs' lard. It is safe to say that three-fourths of all lard made and used contains cotton-seed oil, in proportions from ten to twenty-five per cent; most of it avowedly; while for many years, leading houses used it secretly, from fear of popular prejudice. At present the tide of public opinion seems to be setting in favor of its use; and the principal refiners not only admit that they use it, but take pains to have that fact known, as an argument in favor of the purity, cleanliness and healthfulness of the product.

The refined lard of thirty-five or forty years ago was made by pressing out from the regular lard about fifty per cent. of the oil that it contained, leaving the stearine, which was combined with that lard. What was left was sold as lard. This naturally made an accumulation of stearine.

Later that stearine was mixed with ordinary lard so as to make the latter firmer, so that it would answer better for exportation to warm climates. As the "shortening" of lard is in the stearine and not in the oil, this lard with which stearine was mixed answered better for cooking purposes than the natural product, and sold at a higher price than the latter. It was known as "refined," the term being a misnomer.

In the old-fashioned manufacture of lard the leaf and trimmings were put in kettles, and the lard tried out by heat applied outside the kettle. This made "prime kettle-rendered lard." Later it became the custom to try out the lard by injecting the steam into the kettle itself, so as to come in contact with the lard and the other materials; the result being that the water and steam dissolved out the gelatinous portions, so that they could be removed, leaving the lard whiter and purer than the kettle-rendered, in which latter the darker gelatinous portions were to a considerable extent dissolved by and contained in the product.

The head and gut fat were rendered together, making "No. 1" lard; then there were various greases, white and yellow, made from the other portions of the animal. The grease was very largely used in making No. 1 and No. 2 lard-oil, for lubricating.

Later the packers "went the whole hog," putting in trimmings and heads and all, making but one "straight" brand, known as "steamed lard." There came a time when the butterine men consumed all the leaf lard that was made, grinding it up and putting it in water at about 112° to get out the fat that they used for their product. This was known as "neutral" lard. Its withdrawal from the prime steam lard lowered the quality of that product, and left it with a bitter taste. To supply the place of the leaf lard which was taken out, and to correct the bitter flavor of the prime steam lard, packers commenced the addition of cotton-seed oil, a pure vegetable product, sweet in taste and smell, and healthful in itself. But it made the lard too soft. To overcome that disadvantage, it was found desirable to use "oleo-stearine" from beef suet. The suet fat was

pressed, and the oil from that, called in the trade "oleo," used in the manufacture of oleomargarine; the stearine left from the pressure being used to harden the lard already softened by the cotton-seed oil.

The "refined lard" of commerce is to-day made of three ingredients: (1) refined packers' lard; (2) pure pressed beef fat (oleo-stearine) and (3) pure refined cotton-seed oil. The beef fat which has too much consistency, is balanced by the cotton-seed oil, which has hardly enough for ordinary temperatures; but both are pure, both are clean, both are nutritious.

One reason for using beef fat is, that hogs' lard has a strong odor which is necessary to tone down by admixture with some other fat or oil. Pure hogs' lard has the disadvantage of not keeping well; rapidly becoming soft and rancid in the merchant's store. Of course it is desirable, if not imperative, that such materials as are added be pure, healthful and nutritious.

There are about twenty-five manufactories of refined lard, containing (in addition to hogs' lard) beef fat and cotton-seed oil; and some concerns use no hogs' lard at all; these being most open in their avowal of the fact, and claiming for their product that it is better than that containing hogs' lard as the principal or secondary ingredient.

Some of the reasons adduced why hogs' lard, as ordinarily made, should not be used, are that the hog is liable to various diseases which may be transmitted to the human system; that in its manufacture by many of the packing houses cleanliness and proper care are not always used; that competition offers a temptation to unscrupulous dealers to buy and use smothered or diseased hogs, and that dirty and objectionable parts of the animal are used.

There was a time when from certain selected portions of corn-fed home-raised hogs there was made, by simple and ordinary domestic process, a lard which was perhaps entirely free from any objectionable features. At present, hogs fed on swill and on distillery grains form a large percentage of those which are killed and packed; many diseased animals are used; the head, feet and entrails, as well as unnameable

parts, are thrown into the rendering tanks to be made into "prime lard," instead of into "white grease;" so that what might be admissible, unchallenged, as an article of food, if properly prepared from pure wholesome materials, is now very open to suspicion. That these are not old wives' tales may be very clearly seen by the testimony brought out at the sitting of the Committee on Agriculture of the House of Representatives, at Washington, in March of 1888. Much of this testimony is so disgusting and revolting that it would be very much out of place in a paper read before a mixed audience.

James Matthews testified, on March 20th of this year, that at the packing house where he worked for several years in making "pure" lard, they put in the pigs' heads, then the feet, then the rough lard and white grease; that there was hair on the heads and hoofs and toes on the feet, and that the white grease was made from guts and paunches and unmentionable parts.

Abram S. Jewell testified, March 2d (page 97), that the white grease was made from sore parts of hogs and hogs which had been smothered in the cars or had died from unnatural causes.

Other witnesses, familiar with the details of the business, and many of the workmen in the packing houses, testified in corroboration of these statements, and also said that crippled and sickly animals and "piggy" sows and those which had dropped their pigs in the cars, were put right into the lard tanks, the same as healthy ones.

The testimony of distinguished analysts and authorities is to the effect that cotton-seed oil is not only perfectly harmless, but more wholesome than hogs' lard. From a mass of such expert opinions, I extract the following:

Extracts from Testimony of Prof. H. W. Wiley before the Committee of Agriculture, United States Senate, Washington, D. C., March 17, 1888.

Q. What would you say of cotton-seed oil when used alone as an article of food?

A. I should say that it was perfectly wholesome.

Q. As wholesome as olive oil or hog fat or lard?

A. Yes, sir.

Q. Or beef fat?

A. Yes, sir; that is, as far as our knowledge of the subject extends.

Q. What relation, so far as you know, does cotton-seed oil bear to olive oil?

A. It is very nearly identical.

Q. From your knowledge of chemistry and also of medicine, please tell us whether there is any property in cotton-seed oil injurious to health?

A. Not so far as I know.

Q. Does that statement also apply to beef stearine used in connection with cotton-seed oil in the manufacture of refined lard?

A. Yes, sir. So far as I know, there is nothing in it injurious to health.

Q. You have stated that, so far as you know, this cotton-seed oil has no property that is injurious to health?

A. That is what I stated.

Q. Are the nutritive qualities of cotton-seed oil equal to the nutritive qualities of pure lard?

A. I should say there would be very little difference as far as nutritive properties are concerned.

From

"FOOD ADULTERATION,"

By

JESSE P. BATTERSHALL, Ph.D., F.C.S., Chemist United States Laboratory, New York City, 1887.

As a result of the publicity lately given to the subject of food adulteration, a popular impression has been produced that any substance employed as an adulterant of, or a substitute for another is to be avoided *per se*. Perhaps the common belief that for all purposes cotton-seed oil is inferior to olive oil, and oleomargarine to butter, is the most striking illustration of this tendency. Now, as a matter of fact, pure cotton-seed oil, as at present found on the market, is less liable to become rancid than the product of the olive, and, for many culinary uses, it is at least quite as serviceable. The sale of these products, under their true name, should not only be allowed, but under some circumstances encouraged.

[From *Medical Classics*, New York, December, 1887.]

When, for instance, it becomes understood that the addition of cotton-seed oil to lard is a step in the direction of wholesome and nutritious food and costing the consumer much less than the natural product, a great step forward will have been taken.

The magnitude of the lard industry of the United States may be well imagined, when it is understood that the exports alone in 1887 were 321,523,746 pounds, valued at $22,703,921.

The output of one lard house only (that of N. K. Fairbank & Co.) was, in 1887, 162,847,211 pounds, and will reach this year, 1888, about 200,000,000 pounds. The refined lard industry of this country represents about $15,000,000 per annum, and the cotton seed and cotton-seed oil product, at least $16,000,000. The refuse of a generation ago is now not only an important food for mankind and domestic animals in two hemispheres, but a valuable household cooking material and table delicacy.

Cotton-seed oil-cake is consumed not only in America, but in Great Britain, Germany, Denmark, Norway and Sweden. It is one of the best known animal foods, and has a higher value than any other article, not only for producing milk, fat, bone, etc., but also for manurial uses.

For the purpose of determining the relative and actual values of nitrogenous and non-nitrogenous foods upon the fat and the lean meat of the hog, many careful tests have been made by Profs. W. A. Henry, of the University of Wisconsin, and J. W. Sanborn, of the Missouri Agricultural College. Their experiments showed what might have been suspected: that the nitrogenous food produced the most muscle and the non-nitrogenous the most fat.

The same character of tests were made upon lambs, and the results of these experiments are published by the Agricultural Experiment Station of Cornell University, in its *Bulletin* No. 2, for August, 1888, from which I extract the following facts:

Six six-months' old lambs were taken; and three fed upon oil meal and coarse wheat bran, and later upon cotton-seed meal, oil meal and bran; the other lot of three being given corn meal. Both were fed, during the test, with mixed timothy and clover hay.

It was found that the effect of feeding an undue proportion of non-nitrogenous food to sheep was

(1) To decrease the production of wool by one-fourth;
(2) To decrease the strength of the bones by one-third;
(3) To reduce the production both of fat and of lean meat.

Cotton-seed meal as a food for cattle largely increases the flow of milk, makes richer milk, gives butter and cheese; more and better meat, and richer manure.

Its main value is due to the fact that it supplies the albuminoids and fats which, in hay, straw, corn-stalks and the like, are lacking. It makes rich manure and it may be used to add to poor foods the albuminoids which they lack.

The annexed table, giving the water, ash, digestible nutrients, nutritive ratio, and money feeding-value of various American feeding stuffs, is taken from *Feeding Animals*, by E. W. Stewart.

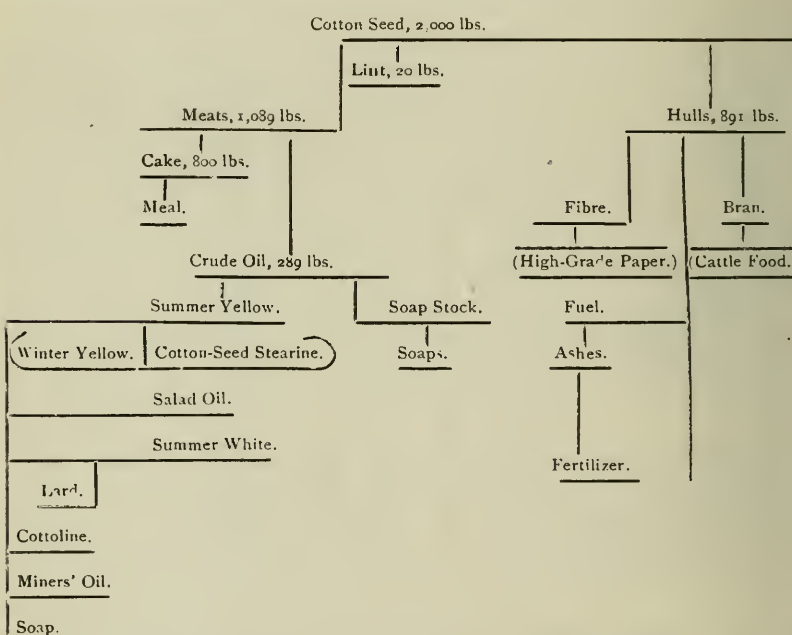
Kind of Food.	Water.	Ash.	Digestible Nutrients.			Nutritive Ratio.	Feeding Value.	
			Albuminoids.	Carbohydrates, Including Fibre.	Fat.		Value per 100 Lbs.	Value per ton of 2,000 Lbs.
	p. c.	*p. c.*	*p. c.*	*p. c.*	*p. c*	*as 1.*		
Clover hay, ...	12·56	6·10	7·82	40·25	1·49	5·6	$0 77	$5 40
Meadow hay, ...	10·50	5·80	4·38	44·55	1·06	10·7	62	12 40
Timothy hay, ...	11·07	4·06	3·67	41·25	1·03	12·7	62	12 40
Oat straw, ...	0·62	5·20	1·44	42 62	0·66	30·6	47	9 40
Wheat straw, ...	6·50	6·96	0·85	37·70	0·54	45 8	39	7 80
Rye straw, ...	11·11	1·84	0·95	37 55	0·54	41·0	40	8 00
Corn stalks, ...	15 00	4·02	1 10	37·00	0·30	34·4	39	7 80
Fodder beets, ...	88·00	0·80	1·10	10·00	0 10	9·3	14	2 80
Potatoes, ...	75·00	0·90	2·10	21·80	0·20	10 6	29	5 80
Turnips, ...	92·00	0·70	1·10	6·10	0 10	5·8	11	2 20
Barley, ...	14·30	2·20	8·00	58·90	1·70	7·9	95	19 00
Oats, ...	14·30	2·70	9·00	43·30	4·70	6·1	98	19 60
Rye, ...	14·30	1·80	9·90	65·40	1·60	7·0	1 08	21 60
Wheat	14·40	1 70	11·70	64 30	1·20	5·8	1 13	22 60
Sorghum seed, ...	12·52	1·80	6·84	53·06	2·99	8·5	90	18 00
Gluten meal, dry, ...	9·15	0·78	23·30	50·92	3 80	2·5	1 63	32 60
Dried sugar meal, ...	8·50	2·00	10 20	54·50	5·40	5·4	1 16	23 20
Glucose sugar meal, ...	72 20	0 10	3 20	19·30	1·80	7·4	39	7 80
Brewers' grains, wet, ...	75·00	1·01	4·06	9 73	1·41	3·2	32	6 40
Brewers' grains, dry, ...	8·19	3·58	14·52	37·41	4·77	3·3	1 20	24 00
Malt sprouts, ...	10·28	5·67	18·82	52·95	0·88	2·3	1 33	26 60
Buckwheat bran, ...	14·00	3·40	13·50	44·00	3·90	4·1	1 15	23 00
Corn bran, ...	12·00	2·30	6·20	55·00	3·60	10·3	92	18 40
Rye bran, ...	11·48	3 68	12·00	48·98	1·43	4·4	89	17 80
Wheat bran, ...	12·42	5 68	11 72	44·66	2·58	4·4	1 02	20 40
Wheat middlings, ...	12·00	3·18	11·60	48·87	2·68	4·7	1 00	20 00
Pea meal, ...	11·40	3 50	20·90	55·40	2·80	3·0	1 53	30 60
Corn meal, ...	15 19	1·48	7·27	63·40	3·29	9 8	1 03	20 60
Linseed cake, ...	10·00	5·97	29·04	33·09	4·53	1·5	1 75	35 00
Linseed-oil meal, old process,	9·20	5 87	25·85	26 52	7·08	1 6	1 66	33 20
Linseed-oil meal, new process,	10·75	5·57	28·25	27·95	2·80	1·3	1 54	30 80
Cotton-seed meal decorticated,	8·33	7·25	35·75	22·25	11 65	1·4	2 25	45 00

As a fertilizer one ton of cotton-seed hull ashes has as much value as four and one-half of average hard wood ashes or fifteen of leached hard-wood ashes.

Two years ago, Messrs. Joseph Sears and Oliver Burnham, of Chicago, started to work out a process to utilize the hulls which were being thrown away or else used as fuel to

run the boilers of the air mills. After long and patient experiment and the expenditure of a large sum of money, they at last have perfected a machine which is now running in St. Louis and is now supplying paper mills with a fibre which comes next to the best of linen in the quality of paper it produces. The fibreless husk, after separating the lint, makes a valuable cattle food. Being rich in carbohydrates it is an excellent material to feed with cotton-seed meal, distillery grains and similar material having too high a nutritive ratio. It is giving the greatest satisfaction and the mill cannot supply the demand. The same is true of the demand for fibre.

The following diagram illustrates the gradual division of the products from a ton of seed :



And now, in conclusion, if I have brought out in this connection any facts or figures which are new and interesting ; if I have pointed out with some emphasis the importance and proportions of the industries which have arisen in con-

nection with what was once a waste, a so-called worthless product; and if in so doing I have in any way encouraged earnest and original-minded men to seek in the wastes of to-day, wealth for themselves and valuable products and processes for the millions' use—the time which I have devoted to the preparation of this paper and that which you have so courteously awarded its reading, will have been well spent.

THE DEBT OF MEDICAL AND SANITARY SCIENCE TO SYNTHETIC CHEMISTRY.

BY PROF. SAM'L P. SADTLER, PH.D.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 28, 1889.*]

The lecturer was introduced by Dr. PERSIFOR FRAZER, Professor of Chemistry in the INSTITUTE, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Writers on the history of chemistry record the existence of a class of *Iatro-chemists*, who succeeded the alchemists proper, and paved the way for the emergence of chemistry as a distinct branch of science from the mists of alchemy. These were medical men who, seeking for additions to their materia medica, turned their time and attention to the pursuit of chemistry. So it comes about that chemistry undoubtedly owes its earliest cultivation, if not its birth, to the followers of the medical profession. Its debt of gratitude for this it has from time to time endeavored to repay in instalments, but is now preparing to square up any balance due, by turning all the resources of modern synthetic methods toward the manufacture of new remedies of therapeutic value. Perhaps the busy physician may say that, if he has to master the nomenclature of modern organic chemistry in order to avail himself of the use of these compounds, it is a doubtful

blessing. But here steps in the enterprising manufacturer and patentee, who coins for him (and copyrights for himself) such suggestive words as "antipyrine," "antifebrine," "aseptol" and "saccharin," and thus allows the practitioner, if he so desire, to prescribe the new remedy without mastering either the chemical formula or the scientific name of the compound.

While the materia medica of the medical profession has been for many years predominantly organic, as distinguished from inorganic or mineral in character, these organic compounds have been taken almost exclusively from the vegetable kingdom. Chemistry has only been asked to perform the minor service of extracting these plant principles and purifying them for use as medicines.

The artificial manufacture of medicinal chemicals was confined to a few important compounds, chiefly anæsthetics, like ether, chloroform and chloral hydrate. The additions to the list of medicinal chemicals of artificial or synthetic manufacture have been so numerous, however, in the last few years, that it seemed desirable to present a classified enumeration of the more important of them, or at least of those in the classes of anæsthetics or hypnotics, antiseptics, analgesics and antipyretics. I have therefore selected this as my subject for this lecture, and will endeavor to group, from the chemical point of view, some of the newer of these compounds, and to look at the question as to whether any correspondence can be made out between chemical grouping and therapeutic action.

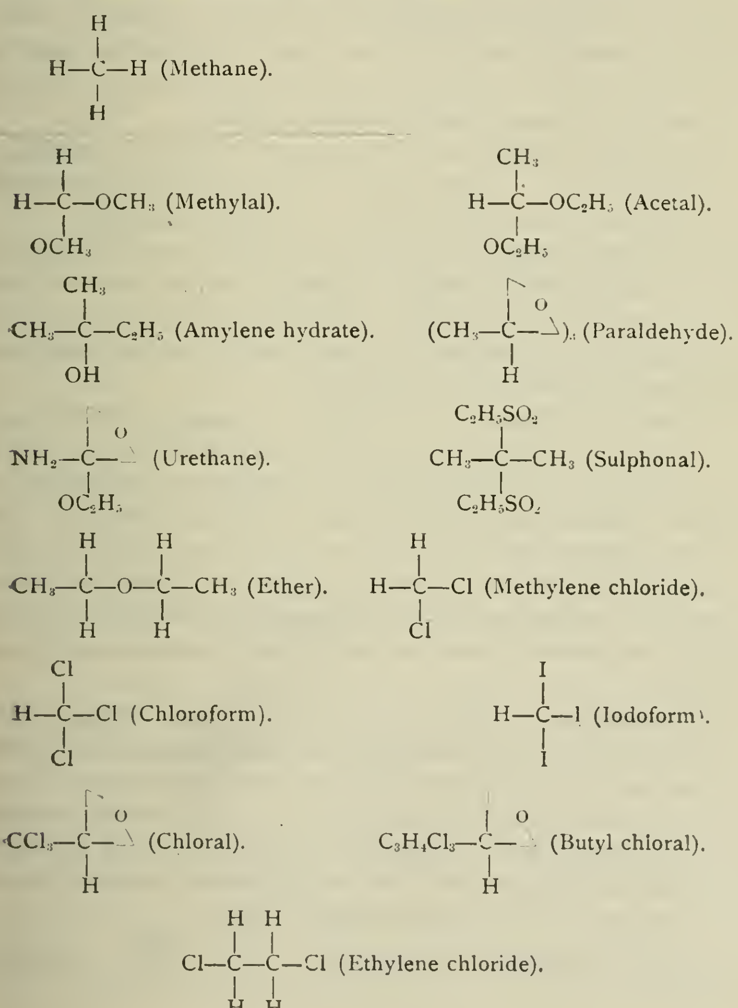
I have put, in Class I, all the derivatives of methane, including with the newer ones, ether, chloroform, iodoform and chloral hydrate for comparison; in Class II, phenols and allied compounds; in Class III, other phenyl derivatives; in Class IV, pyrrol derivatives; and in Class V, quinoline derivatives.

CLASS I.—METHANE DERIVATIVES.

Methylene dimethylic ether (methylal), . . .	$CH_2,(OCH_3)_2$
Ethylidene diethylic ether (acetal), ...	$CH_3,CH,(OC_2H_5)_2$
Tertiary amyl alcohol (amylene hydrate), . .	$(CH_3)_2,C,(C_2H_5)OH$
Paraldehyde, ...	$(CH_3CHO)_3$
Ethyl carbamate (urethane), ...	$CO\begin{cases}NH_2\\OC_2H_5\end{cases}$

Diethylsulphon-dimethyl-methane (sulphonal),	$(CH_3)_2,C,(C_2H_5SO_2)_2$
Ethylic ether, ...	$(C_2H_5)_2O$
Methylene chloride (dichlor-methane), . . .	CH_2Cl_2
Chloroform (trichlor-methane), ...	$CHCl_3$
Iodoform (triiodo-methane), ...	CHI_3
Chloral hydrate, ...	$CCl_3,CHO+H_2O$
Butyl-chloral hydrate (croton chloral), . . .	$C_3H_4Cl_3,CHO+H_2O$
Ethylene chloride.	C_2H_4,Cl_2

The relationship of these, apparently somewhat diverse, compounds, is more clearly seen if we express them in graphic formulæ, alongside of the formula of methane.



NOTES ON THE CHEMICAL AND THERAPEUTIC CHARACTERS OF COMPOUNDS IN CLASS I.

(1) *Methylene Dimethylic Ether* (Methylal). $CH_2(OCH_3)_2$.—Is made by distilling methyl alcohol with sulphuric acid in the presence of maganese dioxide. Is a colorless liquid, sp. gr. 0·855 at 17° C., boils at 42° C., and has an odor resembling that of chloroform and acetic ether, with warm, aromatic taste. Is soluble in alcohol, ether and in three parts of water. Its vapor is not inflammable. It is a soporific, producing quiet sleep. The patient, however, becomes rapidly used to it, so that it must be used in increasing doses. Is claimed to be an antidote to strychnine poisoning when hypodermically used.

(2) *Ethylidene-diethylic Ether* (Acetal). $CH_3,CH,(OC_2H_5)_2$.—Is obtained as a by-product of the alcohol or aldehyde manufacture, or can be made direct from aldehyde. Is a limpid liquid, sp. gr. 0·821 at 22° C., and has a boiling-point 104° C. Is soluble in eighteen parts of water at 25° C., but miscible with alcohol in all proportions. Is given internally as a narcotic, in doses of one and one-half to two and one-half drachms (five to ten grammes).

(3) *Amylene Hydrate.* C_5H_{11},OH.—Is prepared from amylene C_5H_{10} and sulphuric acid and water at 0° C. Is a clear fluid, with an odor reminding one slightly of camphor. Is soluble in eight parts of water; also soluble in alcohol. Has a sp. gr. 0·812 at 12° C., and a boiling-point 102° C. Is used as a soporific, one fluid drachm producing sleep for six to eight hours without unpleasant secondary effects; seems to be intermediate in power between chloral hydrate and paraldehyde.

(4) *Paraldehyde.* $(C_2H_4O)_3$.—Is formed from ordinary aldehyde, by the action of small quantities of sulphuric or hydrochloric acids or salts like $ZnCl_2$ at ordinary temperatures. Is a colorless liquid, boiling at 124° C., sp. gr. 0·9943 at 20° C. Requires twelve parts of water for solution. Is a hypnotic like chloral hydrate, but not so depressing on the heart; also acts as an anæsthetic in larger doses.

(5) *Ethyl Carbamate* (Urethane). $CO\left\{\begin{matrix}NH_2\\OC_2H_5\end{matrix}\right.$.—Is made

by the action of ammonia upon ethyl carbonate, urethane and ethyl alcohol being formed, or by heating urea nitrate and alcohol to 120° to 130° C., when ammonia is given off. It forms colorless crystals of slight ethereal odor and tastes like saltpetre; is soluble in water and alcohol. Melts at 47° to 50° C., and boils without decomposition at 180° C. Is used as a soporific, but does not produce a comatose state like chloral hydrate. Is said to be specially adapted for use as a soporific with children.

(6) *Sulphonal.* (Diethyl Sulphon-dimethyl-methane). $(CH_3)_2,C,(C_2H_5SO_2)_2$.—Forms heavy colorless prismatic crystals, melting at 125°·5 C.; not very soluble in cold water, more readily in boiling water, in alcohol and alcoholic ether. Is a hypnotic of value, especially in the insomnia of the insane and similar cases.

(7) *Methylene Chloride.* CH_2Cl_2.—Is a colorless liquid, having a chloroform-like odor and neutral reaction. Is soluble in alcohol and ether. Was first introduced by Dr. B. W. Richardson, some years ago, as an anæsthetic, but was impure, and several deaths followed its use. Latterly, having been obtained quite pure, it has been successfully reintroduced. It has a sp. gr. 1·349 at 14° C., and boils at 40° C. It is pleasant to inhale.

(8) *Butyl Chloral Hydrate.* $C_3H_4Cl_3,CHO + H_2O$.—Is prepared by passing chlorine into acetaldehyde, until it ceases to be absorbed, and then rectifying and collecting that fraction boiling at 163° to 165° C. This is crystallized with water. Forms white scales of a silky lustre, a peculiar fruit-like odor, warm, bitterish taste and neutral reaction. It melts at 78° C., and is freely soluble in alcohol, ether, glycerine and hot water. It is a valuable hypnotic, producing quiet sleep without impairing the muscular tone of the body.

(9) *Ethylene Chloride.* $C_2H_4Cl_2$.—This is rather taken as representative of a class of chlorinated bodies, which includes, besides this compound, *ethyl chloride*, C_2H_5Cl; *ethylidene chloride*, $CH_3,CHCl_2$ (isomeric with ethylene chloride, CH_2Cl,CH_2Cl) and *carbon tetrachloride*, CCl_4. These all possess hypnotic and, in some degree, anæsthetic properties, but have not met with general acceptance, because of apparent injurious after-effects.

If now an effort be made to find some connection between chemical constitution and therapeutic effect, we at once step upon uncertain ground. The systematic testing of the several classes of methane derivatives has not been carried far enough to enable us to speak with much certainty as to the effect of the compounds as classes, and above all, in many cases, the compounds tried have not always been chemically pure. The chlorinated side-products of the chloroform made from alcohol afford an illustration of this. Unless a substance can be purified by recrystallization, as in the case of chloral hydrate, or be gotten of absolutely fixed and uniform boiling-point, we have no assurance of its purity.

Still we can recognize several general features in studying the structural formulæ of the compounds already described. The chlorinated derivatives of methane all show hypnotic character, advancing in the case of several to the character of anæsthetics, which, however, may or may not be accompanied by other effects which limit their safe application.

The introduction of the methyl and oxymethyl groups (CH_3 and OCH_3) and the ethyl and oxyethyl groups (C_2H_5 and OC_2H_5) in place of the hydrogen of the methane molecule apparently gives us also compounds of hypnotic character, as illustrated in methylal, acetal, amylene hydrate, sulphonal and urethane.

These slight indications, which, as said, must be taken with reserve, may then serve to point out some other compounds as possessing in all probability analogous therapeutic character. Thus, both the methyl and the ethyl orthoformic ethers, $CH,(OCH_3)_3$ and $CH,(OC_2H_5)_3$, and what is known as tribasic acetic ether, $CH_3,C(OC_2H_5)_3$, are sufficiently analogous to methylal and acetal to have similar effects; trichloracetal, $CCl_3,CH,(OC_2H_5)_2$, stands in chemical composition related to both acetal and to chloral and should have analogous character; tertiary butyl alcohol, $(CH_3)_3,COH$, should be analogous to amylene hydrate (tertiary amyl alcohol). As said, these are probabilities, but some of them may fail. The old adage says: "The proof of the

pudding is in the eating of it," and until they are tried, we cannot speak with any certainty.

CLASS II.—PHENOLS AND ALLIED COMPOUNDS.

Phenol (carbolic acid),	$C_6H_5(OH)$
Cresol (cresylic acid),	$C_6H_4(CH_3)OH$
Resorcin (metadioxybenzol),	$C_6H_4(OH)_2$
Hydroquinone (paradioxybenzol),	
Thioresorcin,	$C_6H_4(SH)_2$
a-Naphthol,	$C_{10}H_7,OH$
β-Naphthol,	
Tribromphenol,	$C_6H_2Br_3,OH$
Trichlorphenol,	$C_6H_2Cl_3,OH$
Salicylic acid,	$C_6H_4(OH),COOH$
Phenyl salicylate (salol),	$C_6H_4(OH),COOC_6H_5$
β-Naphthyl salicylate (betol),	$C_6H_4(OH),COOC_{10}H_7$
a-Oxynaphthoic acid,	$C_{10}H_6(OH),COOH$
Orthophenol-sulphonic acid (aseptol),	$C_6H_4(HSO_3),OH$
Di-iodophenol-sulphonate (soziodol),	$C_6H_2(HSO_3)I_2,OH$

These compounds all contain the phenol group (OH) with the exception of thioresorcin, in which the corresponding SH group replaces it. They do not exhaust the list of phenol-like bodies, as creasol and quaiacol of wood tar, thymol contained in several essential oils and pyrocatechin and pyrogallol might be included, but the list has been limited to strictly synthetic compounds of medicinal or sanitary value.

NOTES UPON THE CHEMICAL AND THERAPEUTIC CHARACTER OF COMPOUNDS IN CLASS II.

(1) *Cresol* (Cresylic Acid). $C_6H_4(CH_3)OH$.—Accompanies phenol or carbolic acid in coal tar. As extracted from coal tar, it is a mixture of the three isomeric cresols, and has a sp. gr. of 1·039 to 1·044. It differs from carbolic acid in being liquid, less soluble in water and boiling at a higher temperature. It is claimed for cresylic acid that its antizymotic action is superior to that of carbolic acid, one part of a two per cent. solution added to ten parts of a fermenting liquid stopping all further fermentation.

(2) *Resorcin* (Metadioxybenzol). $C_6H_4(OH)_2$.—When pure forms white crystals with a faint odor and sweetish, acrid

taste. Is easily soluble in water, alcohol and ether. Is used both externally and internally as an antiseptic and anti-fermentative, being free from the highly toxic character of phenol.

(3) *Hydroquinone* (Paradioxybenzol). $C_6H_4(OH)_2$.—Forms colorless prisms soluble in seventeen parts of water at 15° C., more readily soluble in alcohol and ether. It melts at 169° C. Is changed to quinone by the action of oxidizing agents. It is claimed for it that in many instances it is to be preferred to resorcin, as it reduces temperature in much smaller doses, and is the foremost of the antiseptic and anti-fermentative phenols. It has recently been introduced into photography as a substitute for pyrogallol.

(4) *Thioresorcin.* $C_6H_4(SH)_2$.—Yellowish-gray flocculent powder. Is insoluble in ordinary solvents, soluble freely in solutions of the alkalies, alkaline carbonates and alkaline sulphides. Powerful and non-irritant antiseptic. Is used also as a substitute for iodoform.

(5) *α-Naphthol.* $C_{10}H_7,OH$.—Crystallizes in shining needles, melts at 95° C., boils at 278° to 280° C., and readily volatilized. Is prepared from *α*-naphthylamine or from *α*-naphthalene-sulphonic acid. Is an antiseptic of extraordinary efficiency in hindering the development of pathogenic micro-organisms. Its anti-zymotic effect in preventing the alcoholic fermentation in glucose solutions is very strong. (1 : 10·000 of glucose).

(6) *β-Naphthol.* $C_{10}H_7,OH$.—Occurs in colorless or grayish silky leaflets with faint phenol-like odor and burning taste. Melts at 123° C., and boils at 286° C. Is not very soluble in cold water, but much more soluble in hot, readily soluble in alcohol, ether, benzol, chloroform and in alkalies. Is used as an antiseptic and for external application in skin diseases.

(7) *Tribromphenol.* $C_6H_2Br_3,OH$.—Soft white needles, melting at 95° C., and subliming unchanged at higher temperatures. Soluble in alcohol, ether and chloroform, not in glycerine. Readily soluble in caustic alkalies from which it is separated unaltered by acids. Is used as an antiseptic dressing and disinfectant in purulent and gangrenous pro-

cesses. According to experimenters it does not cauterize the mucous membranes of the mouth, nose or pharynx.

(8) *Trichlorphenol.* $C_6H_2Cl_3,OH$.—Is the chief product of the action of chlorine upon phenol. Forms needles, melting at 68° C., and boiling at 244° C. Is easily soluble in alcohol and ether. Used for antiseptic dressings and as a germicide. Also, used in Germany very effectively for erysipelas. Its antiseptic power is said to be twenty-five times as great as that of phenol.

(9) *Salicylic Acid.* $C_6H_4(OH),CO\,OH$.—Is now made by Von Heyden's successors, under Kolbe's patent, as improved by Schmidt, C_6H_5ONa (sodium phenol) + CO_2 = C_6H_4ONa $CO\,OH$ (sodium phenol-carbonic acid). This later compound, when heated to a temperature of 140° C. under pressure, undergoes molecular rearrangement and yields $C_6H_4(OH)$ $CO\,ONa$ (sodium salicylate) from the solution of which the acid is precipitated by hydrochloric acid. Salicylic acid is used both as such and as sodium salt. Used both internally and as antiseptic for water, milk, meats and foods.

(10) *Phenyl Salicylate* (Salol). $C_6H_4(OH),CO\,OC_6H_5$.—Is made by the combination of salicylic acid and phenol. Forms a white tasteless powder of faint aromatic odor, insoluble in water, but soluble in alcohol. It seems to combine the qualities of phenol and salicylic acid, and it is supposed that these substances are liberated from it by the decomposing influence of the pancreatic juice. It is used in rheumatism, neuralgia, and is also a powerful antipyretic and antiseptic.

(11) *β-Naphthyl Salicylate* (Betol or Naphthalol). C_6H_4 $(OH),CO\,OC_{10}H_7$.—Is a compound analogous to salol, but obtained from β-naphthol and salicylic acid. Is in white micaceous scales, melting at 95° C., nearly insoluble in water, easily soluble in boiling alcohol, odorless and tasteless. Is not decomposed by acids or the gastric juice, but, like salol, is decomposed by the pancreatic juice. Is analogous in uses to salol, but not so widely useful.

(12) *Orthophenol-Sulphonic Acid* (Aseptol). $C_6H_4(HSO_3)$. OH.—Is a pinkish or yellowish liquid, having an odor resembling carbolic acid, and a gravity of 1·45. It is readily

soluble in water, alcohol and glycerine. The trade-name "aseptol" is given to a thirty-three and one-third per cent. solution of the acid. It is antiseptic, and is said not to be poisonous or irritant. It has, therefore, been found adapted in dilute solution for ophthalmological practice.

(13) *Di-iodophenol Sulphonate* (Soziodol). $C_6H_2(HSO_3)I_2$, OH.—Is a white crystalline powder, slightly acid in taste, without odor. Melts at over 200° C., and is decomposed, giving off violet vapors. Scarcely soluble in cold or hot water; not readily soluble in alcohol. The sodium salt is, however, easily soluble in water, alcohol and glycerine. The sodium, potassium, mercury and zinc salts have been therapeutically examined. The salts and the free acid are now extensively used for both external application as a substitute for iodoform, internally, and for insufflations. It contains from fifty-two to fifty-four per cent. of iodine.

(14) *α-Oxynaphthoic Acid.* $C_{10}H_6(OH)CO OH$.—Is formed from *α*-naphthol by methods analogous to those used for the preparation of salicylic acid from phenol. It is an almost white crystalline powder, nearly free from odor, very irritating to the nostrils and of pungent taste. Is insoluble in water, but soluble in alkalies, moderately soluble in alcohol, but less so in chloroform and benzine. Is said to be five times stronger as a disinfectant than salicylic acid and proportionally more fatal to bacteriæ and animal parasites.

This class of phenols, naphthols and derived compounds are at once seen to include the most important of antiseptics and anti-fermentations now known. The distinct germicide character of many of them makes them very important in preventing the spread of these minute and dangerous forms of life. There are, no doubt, many additional compounds that will ultimately be brought into this class of agents. The phenols and naphthols, the aromatic acids, like benzoic, toluic and phthalic, and the mixed phenol acids like salicylic and oxynaphthoic acids, together with a long list of their derivatives, will, in the end, be ranked here.

CLASS III.—OTHER PHENYL DERIVATIVES.

Acetophenone (hypnone), ...	$C_6H_5.CO.CH_3$
Acetanilide (antifebrine), ...	$C_6H_5.NH.C_2H_3O$
Brom-acetanilide, ...	$C_6H_4Br.NH.C_2H_3O$
Benzanilide, ...	$C_6H_5.NH.C_7H_5O$
Acetyl-amidophenol, ...	$C_6H_4(OH).NH.C_2H_3O$
Para-acetphenetidine (phenacetine), ...	$C_6H_4(OC_2H_5).NH.C_2H_3O$
Acetyl-phenylhydrazine (pyrodine), . . .	$C_6H_5.N_2H_2(C_2H_3O)$
Phenylhydrazine-levulinic acid (antithermin), ...	$C_6H_5.N_2H(CH_3).C.(CH_2)_2CO\,OH$
Benzoyl sulphinide (saccharin), ...	$C_6H_4\left\langle\begin{matrix}CO\\SO_2\end{matrix}\right\rangle NH$

NOTES ON THE CHEMICAL AND THERAPEUTIC CHARACTERS OF COMPOUNDS OF CLASS III.

(1) *Acetophenone* (Hypnone). C_6H_5,CO,CH_3.—Is formed by distilling a mixture of calcium benzoate and calcium acetate. Forms large crystalline scales or plates, melting at 20°·5 C., and boiling at 202° C. Sp. gr. 1·032. Has an odor recalling bitter almonds, is not soluble in water or glycerine, but soluble in alcohol, ether and chloroform. Is recommended as a hypnotic and used hypodermically.

(2) *Acetanilide* (Antifebrine). C_6H_5,NH,C_2H_3O.—White crystalline scales or needles according to the solvent from which re-crystallized, melting at 120° C., and boiling at 292° C., and sublimable. Is odorless and tasteless. Difficultly soluble in cold water (1 in 60) and hot water (1 in 50), easily soluble in alcohol, ether, chloroform and benzol. Is used as a sedative, a febrifuge and an antipyretic, and in neuralgic and rheumatic affections.

(3) *Brom-acetanilide.* C_6H_4Br,NH,C_2H_3O.—The para compound is made by adding the theoretical amount of bromine to a solution of acetanilide in glacial acetic acid and then purifying by recrystallization out of alcohol. Forms colorless prismatic needles, melting at 165°·4 C. Moderately soluble in alcohol; insoluble in cold water. Is supposed to combine the sedative effects of bromides with the antifebrile effects of acetanilide.

(4) *Benzanilide.* C_6H_5,NH,C_7H_5O.—Is made by the action of benzoic acid upon aniline. When recrystallized out of alcohol forms white pearly scales with faint purplish tinge.

Fuses at 163° C. Insoluble in water; soluble in alcohol; difficultly soluble in ether. Said to be analogous in therapeutic character to acetanilide.

(5) *Acetyl-amidophenol.* $C_6H_4(OH).NH.C_2H_3O$. — Is prepared by dissolving amidophenol in hot acetic anhydride and then precipitating out the compound on the addition of water. Forms scales, melting at 201° C. Easily soluble in alcohol and hot water; soluble also in alkalies.

(6) *Para-acetphenetidine* (Phenacetine). $C_6H_4(OC_2H_5),NH,C_2H_3O$.—Forms a white crystalline powder perfectly tasteless and odorless, melting at 135° C. Slightly soluble in water, hot or cold, somewhat more so in glycerine, but freely soluble in alcohol and ether. Is said to be a reliable antipyretic and anti-neuralgic, the dose being half that of antipyrine.

The ortho-acetphenetidine has also been tried and found to be of similar character.

(7) *Acetyl-phenylhydrazine* (Pyrodine). $C_6H_5,N_2H_2(C_2H_3O)$.—Is a white crystalline powder; very sparingly soluble in cold water.

Is a powerful antipyretic, much more so than antipyrine, antifebrine or phenacetine, but also much more toxic than these bodies. Hence must be administered with proper care and observation.

(8) *Phenylhydrazine Levulinic Acid* (Antithermine). $C_6H_5,N_2H(CH_3),C,(CH_2)_2CO\,OH$.—Is prepared by dissolving phenylhydrazine in dilute acetic acid and then adding a solution of levulinic acid. This causes a yellow precipitate to form, which crystallized from alcohol is gotten in well-formed prismatic crystals. Is said to be a powerful antipyretic.

(9) *Benzoyl Sulphinide* (Saccharin). $C_6H_4\left\langle\begin{matrix}CO\\SO_2\end{matrix}\right\rangle NH$.—This interesting substitute in sweetening effect for sugar is a white powder of slight odor of oil of bitter almonds, especially noticeable when heated. Slightly soluble in cold water; more readily in boiling water. Reacts acid and has an intensely sweet taste, said to be 280 times as strong as cane sugar. Is readily soluble in alcohol. It passes

through the system unchanged and unabsorbed. It acts, moreover, as an antiseptic and anti-fermentative.

It will be seen on looking at this list that we have among them a number of anilides and derivatives of the same. This observation, of course, points out the possibility of similar character attaching to other derivatives, and the analogous character of derivatives of toluidines on the one hand, and diphenylamine on the other. The study of the chemical character of "saccharin" has already led to discoveries of analogous compounds. I am permitted, by my friend Prof. Remsen, in whose laboratory saccharin was originally discovered, to show this evening three of these derivatives of saccharin, which possess great interest in this connection. They are $C_6H_3Br \left\{ \begin{matrix} CO \\ SO_2 \end{matrix} \right\rangle NH$ (brombenzoic sulphinide), $C_6H_3(NO_2) \left\{ \begin{matrix} CO \\ SO \end{matrix} \right\rangle NH$ (nitro-benzoic sulphinide), and $C_6H_3(NH_2) \left\{ \begin{matrix} CO \\ SO_2 \end{matrix} \right\rangle NH$ (amido-benzoic sulphinide). The first is sweet when tasted by the tip of the tongue and bitter at the base of the tongue; the second is intensely bitter, and the third is intensely sweet. Prof. Remsen has also prepared the chlorine and the fluorine derivatives; the former, like the bromine compound, is both bitter and sweet, the sweet taste predominating; on the other hand, the fluorine compound, strange to say, is sweet like the amido compound.

Class IV.—Pyrrol and Pyrazol Derivatives.

Tetraiodopyrrol (iodol), ...	C_4HI_4N
Diphenyl-methyl-pyrazol, ...	$C_3(C_6H_5)_2,(CH_3)HN_2$
Phenyl-dimethyl-pyrazolon (antipyrine), . .	$(C_6H_5)(CH_3)_2C_3HN_2O$

NOTES ON THE CHEMICAL AND THERAPEUTIC CHARACTERS OF GROUP IV.

(1) *Tetraiodopyrrol* (Iodol). C_4HI_4N.—Forms yellowish-gray, fine, light powder. Feels like talc between the fingers. Is almost insoluble in water, but easily soluble in alcohol; soluble also in ether. Is decomposed at the boiling point of alcohol. Tasteless and odorless. It contains

nearly eighty-nine per cent. of iodine. Is about equal to iodoform in antiseptic power, but free from all toxic effects.

(2) *Diphenyl-methyl-pyrazol.* $C_3(C_6H_5)_2,(CH_3)HN_2$.—Forms white needles, melting at 150° C. Difficultly soluble in water, ligroïn and ether; easily soluble in alcohol and glacial acetic acid. Is distinguished from antipyrine by its distinctly basic character. Is said to act like antipyrine, and to be used under analogous conditions.

(3) *Phenyl-dimethyl-pyrazolon* (Antipyrine). $(C_6H_5)(CH_3)_2C_3HN_2O$.—Forms a white crystalline powder or in scales, and is very soluble in water. It melts at 113° C. Its most characteristic reactions are with ferric chloride, with which it turns dark red, and with nitrous acid, or nitrites, with which it turns emerald green. It is one of the most successful of antipyretics, and is used as well for its analgesic effects, as a remedy for sea-sickness, etc.

Class V.—Quinoline Derivatives.

Quinoline, ...	C_9H_7N
Methyl-tetrahydroquinoline sulphate (M. Kairoline), ...	$C_9H_{10}N(CH_3),H_2SO_4$
Ethyl-tetrahydroquinoline sulphate (A. Kairoline), ...	$C_9H_{10}N(C_2H_5),H_2SO_4$
Methyl-tetrahydro-oxyquinoline hydrochlorate (M. Kairine), ...	$C_9H_{10}NO(CH_3)HCl+H_2O$
Ethyl-tetrahydro-oxyquinoline hydrochlorate (A. Kairine), ...	$C_9H_{10}NO(C_2H_5)HCl$
Tetrahydroparaquinanisol (thalline), . . .	$C_9H_{10}N(OCH_3)$
Ethyl-tetrahydroparaquinanisol (ethyl-thalline), ...	$C_9H_9(C_2H_5)N,(OCH_3)$
Methyl-trihydro-oxyquinoline carbonate of sodium (thermifugin), ...	$C_9H_9(CH_3)N,CO\ ONa$

NOTES ON THE CHEMICAL AND THERAPEUTIC CHARACTERS OF GROUP V.

(1) *Quinoline* (Chinolin). C_9H_7N.—Quinoline is a nitrogenous base found in coal tar and in bone oil. It is, moreover, made synthetically by Skraup's synthesis from aniline, nitrobenzol and glycerine. Several of its salts have been tried in medicine, prominent among which is the tartrate. This is in the form of a white micaceous crystalline powder, of pungent odor and sharp, though not unpleasant taste.

It is an antipyretic although inferior to the others in this group.

(2) *Ethyl and Methyl-tetrahydroquinoline sulphates* (Ethyl and Methyl-Kairoline) $C_9H_{10}N(C_2H_5),H_2SO_4$ and $C_9H_{10}N(CH_3),H_2SO_4$. In both cases, the acid sulphate was used, and their action is similar to but slower than that of kairine salts. They are not now in use.

(3) *Methyl and Ethyl-tetrahydro-oxyquinoline hydrochlorates* (Methyl and Ethyl-Kairine) $C_9H_{10}NO(CH_3)HCl + H_2O$ and $C_9H_{10}NO(C_2H_5)HCl$. The methyl salt is that generally known as "kairine." It is a grayish or yellowish crystalline powder of slight phenol-like odor, and of saline-bitter and somewhat aromatic taste. It is difficultly soluble in cold, more easily in hot water; difficultly soluble in alcohol and glycerine, and nearly insoluble in ether, chloroform and carbon disulphide. It melts at 110° C. It is an antipyretic, but has to be given in repeated large doses, and has been replaced in practice by antipyrine, acetanilide and later compounds.

(3) *Tetrahydroparaquinanisol and its Ethyl Derivative* (Thalline and Ethyl-thalline). $C_9H_{10}N(OCH_3)$.—Thalline itself crystallizes in rhombic crystals fusing at 40° C., of a peculiar, pleasant aromatic odor, and soluble in water, ether and alcohol. The salts that have been used are the tartrate, the tannate and the sulphate. The latter, now known as the commercial "thalline," is a white crystalline powder, which fuses at 110° C., and is moderately soluble in water, but difficultly in cold alcohol. A drop of ferric chloride solution produces a beautiful dark-green color, which, in the course of a day, becomes red and ultimately yellow. The reaction will show in extremely dilute solutions. The name is due to this reaction, which is produced by a variety of oxidizing agents. It is a very efficient and rapid antipyretic, and is said to be best administered in repeated small doses, so as to produce cumulative effect. Is particularly recommended for typhoid fevers.

(4) *Methyl-trihydro-oxyquinoline carbonate of sodium* (thermifugin). $C_9H_4(CH_3)N.CO\,ONa$.—The acid was recently discovered by Nencki, of Basel. Its sodium salt, the "thermi-

fugin," has been found by Dr. Demme, of Berne, to be an interesting antipyretic. It is said to combine the three effects of reducing temperature, of retarding the pulse, and of increasing the blood pressure. The free acid forms beautiful crystals, which are but little soluble in water or alcohol, and melt at 265° C. The sodium salt is faintly yellowish-white, lustrous and dissolves to form a brown solution.

With this compound is completed the last or fifth group of compounds selected for mention. These five groups, however, do not cover the whole ground of synthetic compounds introduced into medicine in recent years. Liebermann showed, in 1878, that a reduction product of chrysophanic acid $C_{15}H_{10}O_4$, to which he gave the name of chrysarobin, and the formula $C_{30}H_{26}O_7$ was the active principle in Goa powder. Now, as chrysophanic acid is the alizarine of methyl-anthracene, Liebermann determined to investigate the reduction products, or leuco-bodies, as they are termed, of commercial alizarine and purpurine. He has thus discovered recently a series of compounds, to which he gives the names of "*anthrarobins*." The large sample shown is commercial anthrarobin from artificial alizarine. It is a yellowish-white powder permanent in air, insoluble in water and dilute acids, but readily soluble with brown-yellow color in dilute solutions of the alkalies and alkaline earths, the solutions in contact with oxygen passing through green and blue, finally into alizarine-violet. Anthrarobin is used already in many cases of skin diseases. It is said to be intermediate in character between chrysarobin and pyrogallol.

The list of miscellaneous synthetic preparations might be expanded at great length, but my object was not so much to make an enumeration as to classify the more prominent of these compounds.

If the question be asked what limits can be set to the possibilities in the direction of synthetic manufacture, I would remind the inquirer that when W. H. Perkin discovered mauve, the first of the aniline dyes, in 1856, no one could have predicted the enormous development of the coal-tar color industry. So now, it is impossible for us to foresee

how extensive or how rapid will be the development of the manufacture of synthetic remedies. We have yet to accomplish the synthesis of most of the important alkaloids, and it is likely that hundreds, if not thousands, of analogous working compounds will be obtained before all of them are thoroughly investigated.

In conclusion, I must acknowledge my indebtedness to E. Merck, of Darmstadt and New York, to Messrs. Lehn & Finck, W. H. Shieffelin & Co., Roessler & Hasslacher, John Campbell & Co., Eimer & Amend, Lutz & Movius, Wm. Pickhardt & Kuttroff, of New York, and to Drs. S. C. Hooker and H. W. Jayne and Messrs. Bullock & Crenshaw, of this city, for favors in the presentation or loan of specimens for the illustration of this lecture.

University of Pennsylvania,
Philadelphia, January, 1889.

PERMEABILITY OF CEMENTS.

By Lewis M. Haupt.

The desirability of using concrete of cement for lining aqueducts, cisterns, tanks, and for the construction of submarine tunnels, dams, and other works, involves the question of the permeability of the materials, especially when the conduits are subjected to hydrostatic pressure; yet the literature of the subject appears to be very meagre. Doubtless many facts exist of value to engineers on this important subject, but they do not appear to be available to the profession, and the recent discussion upon the possibility of lining the new Washington aqueduct with concrete instead of a brick ring with dry back filling has failed to develop any material facts, but reveals a remarkable difference of opinion amongst those taking part in that discussion. The accompanying paper may be of some service in this direction, and is presented with the view of eliciting further facts from engineers or others who may be interested in the subject. L. M. H.

NOTE ON THE PERMEABILITY OF MORTARS OF PORTLAND CEMENT, AND THEIR DECOMPOSITION UNDER THE ACTION OF THE SEA.

By MM. Léon Durand Claye, Engineer in Chief of Bridges and Roads, and Paul Debray, Assistant Engineer.

[Translated from the *Annales des Ponts et Chausées*, May, 1888, by L. M. Haupt, Professor of Civil Engineering, University of Pennsylvania, for the Journal of the Franklin Institute.]

Until the present time it was generally admitted that mortars, composed of Portland cement, if not absolutely unalterable by sea water, at least were affected only by its destructive action after long exposure, and then only to a small extent.

Several recent accidents have unfortunately impaired general confidence in the use of Portland cements, and show that, to prevent unfortunate contingencies in maritime works, it is *always* necessary to observe the most minute precautions in the mixing of mortars, as well from Portland cement as from hydraulic limes, for use in masonry.

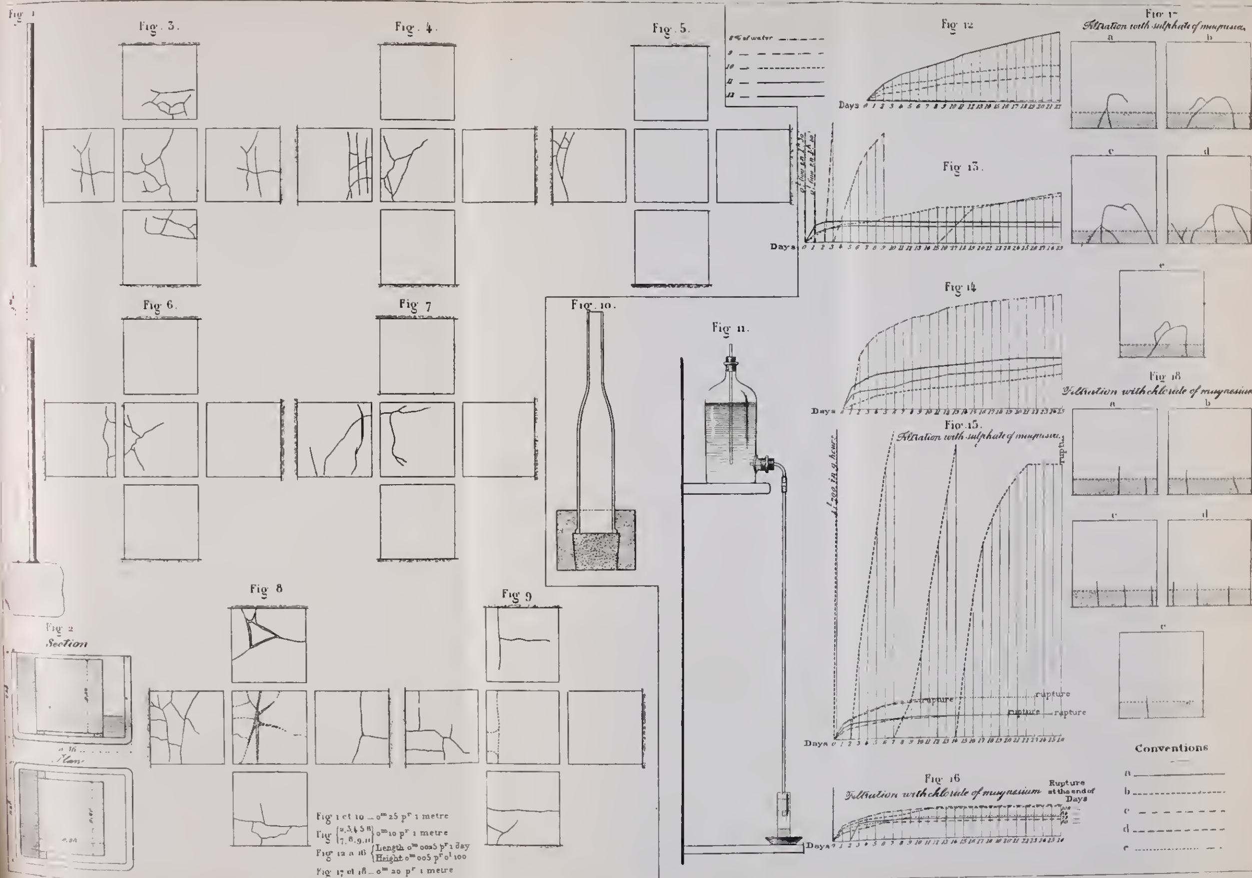
Quay walls, laid in solid mortar, called béton, composed of about 200 kilograms (440 pounds) of Portland cement to each cubic metre of sand, and from 150 to 200 kilograms of water, laid in layers and surmounted by ashlar masonry, were disintegrated by the action of sea water in a very short time, *i. e.*, in less than a year for certain parts of the work.

It has been observed also that the masonry of wet docks gives evidence of movement within the few months succeeding the letting in of the water, and in a short time shows numerous fissures, even where there has been used a Portland cement mortar containing 300 kilograms (660 pounds) of cement per cubic metre of sand for the hearting and 400 kilograms for the facing.

At the request of the Commission on Tests of Cements, we proceeded to analyze numerous specimens collected with care by resident engineers and to seek to explain, by the aid

PERMEABILTY OF MORTARS OF PORTLAND CEMENT. ACTION OF THE SEA.

Pl. 6.



of laboratory experiments, the accidents with which we were impressed.

The present note gives the result of our studies and researches.

(1) ANALYSIS OF THE SPECIMENS.

The samples of "béton de sable," fifteen of which were sent us, were not taken from the same cross-section, nor even from the same part of the quay wall; they are not then justly comparable. Nevertheless, profiting by the suggestions sent us therewith, we have presumed to place them in the same hypothetical section, classifying them from the top to the bottom of the section.

We state hereafter in a table, where the samples are classed in this order, the leading results of our analysis, in percentages of lime, magnesia and sulphuric acid. Accepting the suggestions given us by a member of the Commission on Cement, we give also the weight of magnesia to the sum of the weights of the lime and magnesia. This statement may be regarded as characteristic of the condition of the specimens.

Name of Sample.	Per Cent. of Magnesia.	Per Cent. of Lime.	Relative Weight of Magnesia to the Total Weight of Lime and Magnesia.	Quantity of Sulphuric Acid.
M,	0·25	13·05	0·02	0·05
P,	0·20	13·90	0·01	0·10
L,	0·25	11·40	0·02	0·50
H,	0·30	10·35	0·03	0·05
G,	0·35	9·75	0·03	0·05
E′,	1·60	8·50	0·16	0·30
F,	0·10	10·20	0·01	0·45
D,	0·10	10·10	0·01	0·40
N,	0·45	11·45	0·04	0·60
K_1,	2·90	5·80	0·33	0·60
K_2,	3·90	4·70	0·45	0·40
K_3,	0·35	11·90	0·03	0·95
B,	0·10	9·95	0·01	0·35
C,	0·25	11·35	0·02	0·40
A,	2·70	6·15	0·30	0·60

An inspection of this table shows that the proportion of magnesia and the amount of sulphuric acid are very variable from one specimen to another, which can only be due to the action of the sea water after placing the béton in the water

of the basin. It is also observed that the samples showing the largest amounts of magnesia or sulphuric acid correspond to those parts of the quay walls which suffered most damage.

We give also below the analysis of mortars taken from the masonry joints of the wet-dock, from places where the cracks appeared largest and most alarming.

Name.		Per Cent of Magnesia.	Per Cent. of Lime.	Relative Weight.	Sulphuric Acid.
Mortars from under the banket of the graving dock.	1	3·50	7·65	0·31	1·10
	2	2·70	8·45	0·24	0·85
	3	1·65	8·05	0·17	1·20
Mortars from the curb of the graving dock, .	4	4·50	6·85	0·39	1·55
	5	7·80	10·20	0·43	0·40
	6	4·05	7·40	0·35	1·00

The results of this analysis show distinctly that in the second case as in the first, mortars of Portland cement have been materially changed by the action of sea water.

(2) EXPERIMENTS ON THE PERMEABILITY OF MORTARS.

In perfectly sound specimens, obtained from the highest parts of works where the basins had not yet been filled with water, we have invariably found that béton of sand and mortars were not only very porous, but also very permeable.

We call attention to the fact that it is necessary to make a marked distinction between porosity and permeability. Porosity is the faculty which motars exposed to the air have of absorbing a certain quanity of water whenever they are immersed in a vessel and left there sufficiently long. It is an easy matter to determine the measure of the porosity. For this purpose take any assumed quantity, which is weighed, either immediately or after drying, in a moderate temperature. This gives a known weight (P). The same specimen is again weighed after saturation, giving a greater weight P'. Hence, the porosity is given by the ratio

$$\frac{P' - P}{P}$$

which represents the proportional increase of weight of the

mortar resulting from the absorption of a certain quantity of water which has penetrated the pores and filled the voids occupied by the air.

Permeability is the faculty whereby blocks of mortar submitted to the action of a head of water on one of their faces, transmits through their mass a certain quantity of the water. Other things being equal, the permeability would be measured by the amount of water which passes through in a given time.

It is a very difficult matter, however, to put different blocks of mortar under *equal* conditions, so that the volume of water passing through them may give a *measure* of their relative permeability.

We will explain, subsequently, the apparatus we have prepared to measure the permeability of mortars of different compositions, but without being able to reach very satisfactory results.

Although it is not possible to measure with mathematical accuracy the permeability of specimens of mortars taken from masonry, it is always easy to learn whether or not they are permeable.

It is sufficient to seal upon a fragment of the mortar, whatever its form may be, by means of wax, a glass tube of about a meter in height, and to fill this tube with water. (*Fig. 1*, pl. 6.)

When the mortars are very permeable, the water in the glass tube is seen to fall quite rapidly, and a condensation more or less profuse takes place on the mortar. The experiment may be repeated, as soon as desired, by refilling the glass with water.

The glass tube may also be connected with a "Mariotte" flask, thus maintaining a constant head. But in either case, the irregularity in the form of the specimen under treatment, and the difficulty of noting the influence of this irregularity on the rate of filtration, prevents the giving of a coëfficient of precise value for the permeability of experimental mortars.

Having recognized the permeability of the béton and mortar which we have submitted as susceptible to decom-

position under the action of sea water, we have thought to reproduce the phenomena under investigation by substituting for sea water some solutions of the salts of magnesia.

In a first experiment we have submitted a sound block of "béton de sable" to the action of a six per cent. solution of sulphate of magnesia, applied upon one of the side faces, under a mean pressure of ten centimetres in height. For this purpose, we placed this block in an earthen vessel, as shown in *Fig. 2*. By means of a packing of neat cement we formed, on the left of the block, a sort of reservoir, which was filled each day with the above solution. The water filtered through the block and collected in the other part of the vessel, from which it was withdrawn periodically by a siphon.

From the date of the placing of the specimen it was ascertained that there was produced an expansion in the mass of the block; about the sixteenth day there was visible on the upper face the first fissure three to four centimetres long and perpendicular to the bearings.

The next day another fissure was observed, at right angles to the first, to which it was connected by two light tendrils. This cross fissure soon became of great importance, prolonging itself with accessory cracks to the right and left of the block. (*Fig. 3*, pl. 6.)

At the same time, in consequence of the transverse expansion of the block, the vessel in which it was bound burst on both sides only twenty days after the beginning of the experiment. We were obliged then to cease the filtering of the water, but, nevertheless, the block continued to expand and to crack until we broke it to examine the changes which had taken place in the interior. It was found that the centre was reduced to a white pulp without consistency, precisely like that shown in a greater or lesser degree in the damaged works.

We have recently renewed this experiment with other blocks of "béton de sable" obtained also from the works, mixed with different French, English and Belgian cements. We have treated these blocks as indicated below, with these differences, that the earthen vessel was replaced by one of

galvanized iron and that the packing strips to enclose the reservoir on the side were made of modelling wax in place of cement.

We have also reduced the proportion of the solution of sulphate of magnesia to six parts per 1,000 instead of per 100 to approximate the quantity of the salt to that found in sea water, and not to exaggerate the decomposition of the blocks as we had occasion to do in the first experiments, with the desire to reach an appreciable result with little delay, *which we dared not hope for at first.*

We have obtained the same results with the different blocks under trial, as that was the production of the cements employed in this manufacture; only the phenomena of disintegration and of decomposition are produced in different places with more or less rapidity, according to the amount of filtration. We give also sketches of the results of these experiments in *Figs. 4* to *9*, pl. 6.

We have not made direct tests of decomposition under the action of magnesium solutions, on the fragments of cement mortars of 300 to 400 kilograms, which we have received. They were of irregular form, and not well adapted to experimentation, having been at some time or other submitted, more or less, to the action of the sea.

But we have sought to mix in the laboratory some gauges of mortar well adapted to the filtration tests. Without having yet found a system to satisfy us, we have tried different combinations, which it is perhaps not without interest to explain in detail, to give to experimenters, who may wish to develop the subject further, the useless experiments and discouraging deceptions.

First, then, we tried a mixture in truncated conical moulds of mortar, four centimetres high by five diameter of larger base, and forty-five millimetres for diameter of smaller base. Above these disks, on the side of the larger base, was placed a glass tube, the joint being enlarged, as shown in *Fig. 10*, and enclosed in a mass of pure cement. We made four series of three disks, with the following proportion:

(*a*)	200 kilos of cement	and	200	kilos of water to	1	cubic metre	of fine sand.
(*b*)	200	"	"	150	"	1	"	"
(*c*)	350	"	"	200	"	1	"	"
(*d*)	350	"	"	150	"	1	"	"

In each series we first submitted the disks to filtration with clear water, then with water containing six per cent. of sulphate of magnesia, followed by water containing thirty per cent. of the same salt.

The mortars were very permeable, and we had only to fill the tubes to obtain abundant filtrations. It was not necessary to give a pressure greater than it would have been easy to produce, by splicing the glass tubes by rubber bands over their ends.

These experiments on filtrations were continued about twenty-five days. It was established that in general the disks which had been submitted to water charged with sulphate of magnesia were ruptured to so much greater extent, as the proportion of cement in the mortar was increased; as the proportion of water was reduced, or as the water used for filtering was enriched by the salt.

We have analyzed these disks, and show, by the analyses (see the annexed table):

(1) That filtration with pure water had removed a certain proportion of the lime existing in the mortars and coming from the cements.

(2) That under the action of water charged with sulphate of magnesia, part of the lime contained in the mortars disappear, whilst the proportion of magnesium and of sulphuric acid is found to increase.

We have consequently abandoned this method, thinking that it was preferable not to introduce at the side of the mortars a band of cement, which being submitted to natural agencies, affects the results sought.

We have sought then to obtain in tubes of glass of a convenient diameter (three to four centimetres), some disks of mortar adhering directly without the interposition of any foreign substance.

We procured some ends of strong glass tubes three to four centimetres in diameter and ·12 metres long, and filled

their extremities with disks of cement. (We omit the description of the method of filling the tubes.)

After a few days the disks thus formed are sufficiently adherent to be submitted to a charge of one metre of water, by the apparatus represented in *Fig. 11*, pl. 6.

In our experience each tube was sealed at its upper end by a strong rubber cork, with a round hole for a glass pipe of about one metre in height. Above, on a shelf, a series of Mariotte vases were arranged, containing water from the Seine, or solutions of magnesia. The joints were made by rubber tubing, and thus the cakes were submitted to a uniform pressure, and the quantity of water filtering through was measured either by collecting it, or by noting the lowering of the level in the previously gauged Mariotte vases.

Our experiments have demonstrated that although the filtration was very rapid at first, it diminished rapidly in importance, and in a short time it became, if not absolutely nil, at least very weak. But at the same time we have shown that the tube enclosing the disks cracks or even breaks away from them in consequence of the expansion of the mass. We show (Pl. 6, *Figs. 12, 13* and *14*) the results of experiments made on three series of mortar tablets, made in the proportion of one part of cement to four of sand, by weight, and mixed with water varying from eight, nine, ten, eleven to twelve per cent. of the sum of the weights of cement and sand. The law of decrease of filtration is seen very well, as also the influence which the proportion of water used in tempering has upon the rate.

In the first series, or when the water was nine per cent. of the weight, the filtrations were the least abundant. Mortar made with seven per cent. was very permeable, as is shown on the diagram. That of ten per cent. was more permeable than that of nine or eight per cent., whilst that of eleven per cent. was still greater than that of ten.

In the second series, when the proportion of water was eleven per cent., there was the least filtration. The eight per cent. mortar was so very porous that it was not possible to draw the corresponding curve.

In the third series ten per cent. give the minimum. It

was not possible to represent the filtration curve for eight per cent.

There seems to result from these experiments that for each proportion of mortar and of sand a certain quantity of water corresponds to the maximum density and minimum permeability of the mortars. This phenomenon explains itself naturally if we observe that at the instant of making the disks the grains of sand and cement are in the same state.

Now, we know that sand when quite wet occupies a larger volume than when dry; and that on the other hand it shows a considerable settling when it is covered with water.

The grains of cement are in the same condition, but when the quantity of water is considerable and the material is worked as in the making of mortars, they do not remain in suspension but are combined, at the instant of mixing, at relatively great distances from each other.

We have also studied the comparative action of solutions of sulphate of magnesia and chloride of magnesium in the proportion of six per cent. in two series of five disks mixed with one part of cement to four of sand and ten per cent. of water, mixed in pairs to eliminate, so far as possible, all other influences than those due to the salts employed.

Pl. 6, *Figs. 15* and *16*, show the curves of filtration of these disks, and *Fig. 17* shows one part and *Fig. 18* another, of the several faces surrounding the disks of mortar, reduced in proportion of five to one. The specimens submitted to the action of sulphate were broken from the tenth to the twenty-sixth day of filtration, whilst those submitted to the chloride resisted at least sixty days. It is noticeable also that the cracks in the first case are more numerous and deeper than in the second, indicating a more energetic action. We should add, however, that all the disks preserved their compactness, and that their swelling did not seem to have affected their resistance.

Chemical analysis proves that the disks submitted to the action of the sulphate contained from ·75 to ·80 per cent. of sulphuric acid, from which we conclude that a double decomposition has taken place between the salts of lime

and the sulphate of magnesia, as pointed out long since by Vicat; a part of the sulphate of lime forms and remains in the mass of the mortar.

It is to the production, in masses of mortar of perceptible quantities of sulphate of lime, that we are led to attribute the phenomena of the dislocation of masonry of Portland cement mortar submitted to the action of the sea.

Our analyses appear to us to show, as an indisputable fact, that the sulphate of lime produced by the action of the sea on mortars, is not entirely drawn out by the water which circulates in the masonry, and which plays a very important part in the disintegration of this masonry.

Whilst the magnesia appears to partake of the nature of thin cream without consistency, it is unable to exercise any mechanical action on the masonry; whereas the sulphate of lime solidifies more or less completely in crystals of such a nature as to develop considerable molecular activity.

Paris, 16 January, 1888.

NOTE.—Disks of cement mortar.

The first series were made in the proportion of 200 kilograms of cement and 200 liters of water to each cubic metre of sand; the first disk kept for reference was exposed to the air, the others were submitted to the action of pure water, or to a solution of sulphate of magnesia containing at first six per cent. and second thirty per cent. of the salt filtered through the mass.

Proportion, ... $\begin{cases} \text{1 cubic meter of sand,} \\ \text{200 kilogrammes of cement,} \\ \text{200 litres of water.} \end{cases}$

First Series.	Disks.			
	Dried in Air.	*Traversed by*		
		Pure Water.	Water at 6 Per Cent.	Water at 30 Per Cent.
Insoluble residue,	82·35	80·55	75·40	7[illegible]·9[illegible]
Alumina and peroxide of iron,	1·65	1·65	1·60	1·55
Lime,	10·75	9·35	8·35	8·80
Magnesia,	0·15	0·20	2·30	2·10
Sulphuric acid,	0·05	0·15	2·65	4·25
Loss by heat,	4·80	8·00	9·90	10·40
Error,	0·25	0·10	— 0·20	10·40
Total,	100·00	100·00	100·00	100·00

(2) The disks of the second series were made in the proportion of 200 kilogrammes of cement and 150 litres of water to one cubic meter of sand; these were submitted to the same tests as the first.

Proportion, ... { 1 cubic meter of sand,
200 kilogrammes of cement,
150 litres of water.

Second Series.	Disks.			
	Dried in Air.	*Traversed by*		
		Pure Water	Water at 6 Per Cent.	Water at 30 Per Cent.
Insoluble residue, ...	82·35	78·40	77·00	74·25
Alumina and peroxide of iron, ...	1·50	1·80	1·80	1·75
Lime, ...	10·70	9·55	8·35	8·50
Magnesia, ...	0·10	0·10	2·00	2·20
Sulphuric acid, ...	0·10	0·30	2·00	2·60
Loss by heat, ...	4·90	9·80	8·80	10·75
Error, ...	+ 0·35	+ 0·05	+ 0·05	— 0·05
Total, ...	100·00	100·00	100·00	100·00

(3) This third series of disks was made in the proportion of 360 kilogrammes of cement and 200 litres of water to one cubic meter of sand.

Proportion, ... { 1 cubic meter of sand,
350 kilogrammes of cement,
200 litres of water.

Third Series.	Disks.			
	Dried in Air.	*Traversed by*		
		Pure Water.	Water at 6 Per Cent.	Water at 30 Per Cent.
Insoluble residue, ...	77·00	73·60	67·55	67·65
Alumina and peroxide of iron, ...	2·50	2·50	2·25	2·65
Lime, ...	14·25	12·55	11·35	11·35
Magnesia, ...	0·10	0·05	2·70	2·30
Sulphuric acid, ...	0·10	0·30	4·40	4·95
Loss by heat, ...	6·00	10·95	11·90	11·10
Error, ...	+ 0·05	+ 0·05	— 0·15	11·10
Total, ...	100·00	100·00	100·00	100·00

(4) The disks of the fourth series were made in the proportion of 350 kilogrammes of cement and 150 litres of water for every cubic meter of sand

Proportion, ...	1 cubic meter of sand, 350 kilogrammes of cement, 150 litres of water.

Fourth Series.	Disks.			
	Dried in Air.	Traversed by		
		Pure Water.	Water at 6 Per Cent.	Water at 30 Per Cent.
Insoluble residue, ...	77·05	71·55	68·10	67·70
Alumina and peroxide of iron, ...	2·65	2·45	2·20	2·60
Lime, ...	14·70	12·25	11·15	11·85
Magnesia, ...	0·10	0·15	2·80	2·35
Sulphuric acid, ...	0·10	0·15	4·05	4·50
Loss by heat, ...	5·25	13·50	11·85	11·10
Error, ...	+ 0·25	— 0·05	— 0·15	— 0·10
Total, ...	100·00	100·00	100·00	100·00

ADDENDA BY L. M. HAUPT.

The writer recently had an interview on this subject with Mr. Jno. C. Goodridge, Jr., whose long experience with cements makes him an authority, and learned that in using cement for water tanks it was found that when filled the first time they leaked badly and the water soon escaped, but each time they were refilled the leakage was less, and that in about a week, or after six or seven fillings, they became practically tight and remained so.

In his investigations upon high walls or dams to resist the pressure of water, Major J. B. Francis made some experiments to determine "whether the pressure of water can be communicated through the capillary channels in the mortar. The apparatus consisted of an iron filter connected with pipes and pressure gauges, by means of which a plug of Portland cement, mortar in the proportion of one part of cement to two of sharp pit sand, was subjected to pressure. "The experiment consisted in noting the pressures at the several gauges at the beginning and end of periods, which gave sufficient time for them to become established." * * Unfortunately the case was not a sound casting and there were minute leaks, which materially modified the results.

For full description reference is made to the *Transactions Am. Soc. of Civil Engineers*, October, 1888.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, February 19, 1889.*]

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, February 19, 1889.

Dr. SAMUEL C. HOOKER, Vice-President, in the Chair.

Members present: Dr. L. B. Hall, Dr. H. W. Jayne, Dr. Wm. H. Wahl, Dr. E. H. Keiser, Dr. H. F. Keller, Prof. Henry Trimble, Prof. E. F. Smith, Messrs. W. L. Rowland, F. C. Lewin, A. T. Eastwick, Marshall R. Pugh, T. C. Palmer, Dr. W. C. Day, and a number of visitors.

An abstract of a letter from Prof. Ira Remsen, editor of *The American Chemical Journal*, was read. The letter requested first publication of papers read before the Section.

The Committee on By-Laws, Mr. T. C. Palmer, Chairman, submitted a report, which was read and approved. Accompanying the report was a copy of the revised By-Laws, which was read; a few changes were made and, in order to give time for the full consideration of the By-Laws, they were laid over until the next meeting for final action, the Secretary being instructed to have them printed and to send a copy to each member of the Section.

A report from the Treasurer was read and, in connection therewith, it was recommended that certain delinquent members should be notified that unless arrears be made good their names would be dropped from the list of members; it was also recommended that such notification should be given in all similar cases occurring in future.

The following gentlemen were elected members of the Section: Dr. T. R. Wolf, Newark, Del.; Mr. C. J. Semper, 505 South Forty-first Street, Philadelphia; Mr. S. Lloyd Wiegand, 146 South Sixth Street, Philadelphia; Prof. Edgar F. Smith, Ph.D., University of Pennsylvania; Mr. Marshall R. Pugh, University of Pennsylvania.

Mr. F. Lynwood Garrison was nominated for membership in the Section.

The motion that the annual dues be increased from one dollar to two dollars, the initiation fee remaining one dollar, as heretofore, was carried.

The resignation of Mr. Robert Frazer was accepted.

Mr. T. C. Palmer's paper, "On the Ash of *Tillandsia Usneoides*," a copy

of which was already in the hands of all the members, was read by title. The author requested that those who might be able to contribute information or give reference to papers on this subject would kindly do so, as he is still occupied with the investigation of the way in which this plant obtains its mineral nourishment.

Dr. H. F. Keller then read a paper "On Diacetyl and Some of its Derivatives;" which has been referred for publication.

Diacetyl was first produced by heating ketipic acid, which splits up into carbon dioxide and a yellow volatile liquid which proved to be diacetyl. The facts upon which the structure of this substance is based were considered, as well as the methods of preparation, composition and properties of a number of its derivatives.

Dr. Hooker showed a specimen of benzil, the compound in the aromatic series which corresponds to diacetyl.

Dr. Wahl gave a brief account of some interesting experiments, upon which he is now engaged, in connection with the electrolysis of hydrochloric acid. In electro-plating with platinum and iridium, a number of difficulties present themselves; the solution of metal constantly varies in strength, owing to the fact that the metal is dissolved only in insignificant quantity at the anode, so that the metallic strength of the plating solution is constantly being weakened, requiring frequent additions to be made to the bath. Another difficulty is that the deposit is spongy, black and non-adherent in character, rather than reguline and bright. The first difficulty has been overcome by Dr. Wahl, and he is now working with special reference to the second, with encouraging prospects. Dr. Wahl expects to bring before the Section, in the near future, a paper which will consider in detail his experiments and their results. Professor Smith described a method of determining platinum electrolytically by depositing the platinum from the compound, K_2PtCl_6, on a platinum dish (previously plated with copper), by means of a low current applied for five or six hours; the presence of sulphuric acid is advisable. No platinum could be detected in the liquid after the action. Dr. Wahl then exhibited some specimens of his platinum and iridium plating, which were inspected with much interest by the members.

The Secretary exhibited a specimen of highly bituminous coal from a new source in Alaska.

Adjourned. WM. C. DAY, *Secretary.*

ABSTRACTS.

CAYOTA, A NEW TANNIN. M. Villou (*L'Ind. Text.* and *Textile Colorist*, **11,** 8).—This reddish-brown bark comes from the southern part of Mexico, where it is used for tanning thick sole-leather, to which it is said to impart "strong consistency and great solidity." It is easily powdered, has a resinous odor, and according to Mr. Ebertz, of Berlin, contains twenty-two to thirty per cent. of tannin. The pure tannin, separated by the author, consists of yellow scales, which dissolve in fifteen parts of their weight of cold water, and

in all other solvents for tannin. It colors the salts of iron a fine black, whose intensity is variable according to whether the decoction or extract of the bark is obtained in the cold, or by boiling under pressure or in the presence of oxydizing agents. Its molecular weight is equal to that of the tannin from oak bark. The bark or extract is said to be superior to Quebracho on account of the absence of resin, and to give to silk the suppleness of sumac.

H. T.

ON THE DETECTION OF CAUSTIC ALKALI IN THE PRESENCE OF ALKALINE CARBONATES. L. Dobbin (*Jour. Soc. Chem. Ind.*, December 31, 1888, pp. 829–830).—This method depends on the coloration of dilute solutions of potassium iodide in mercuric chloride, to which ammonium chloride has been added. This reagent gives no coloration or precipitate with sodium or potassium carbonate, but forms a delicate test for caustic alkali, a yellow coloration being produced as soon as a sufficient quantity has been added to change the whole of the ammonium chloride present into potassium salt and free ammonia. By using a reagent containing a very small proportion of ammonium chloride the test is extremely delicate. The quantity of caustic alkali is estimated by color comparison. M. R. P.

ON SOME ABNORMAL SAMPLES OF BUTTER. A. H. Allen (*Analyst*, January, 1889).—Professor Stein, official analyst to the Danish government, having been led to doubt how far the limits generally adopted by public analysts in the examination of butter were to be relied on, an investigation was ordered by the Royal Agricultural Society, and the author invited to take a part in it. Average butter fat takes by the Reichert-Wollery process 29·2 cc. $\frac{n}{10}$ alkali, whereas butter from one of the farms inspected, which had been so closely watched as to render adulteration impossible, took but 24·7 cc., and that from another but 22·3 cc. $\frac{n}{10}$ alkali. Although these butters are exceptional, yet they were produced from the milk of a large number of cows, so it cannot be said that such butter may not be met in practice. Nilson, of Stockholm, found the volatile acids to vary materially with the time since calving. The author also discusses the detection of vegetable oils. In conclusion he recommends that a committee of the Society of Public Analysts receive and tabulate results of analysis, and devise, if possible, some method of examining butter less dependent on the natural variations in its composition, than the methods at present in use. M. R. P.

ARTIFICIAL COFFEE. A. Stutzer (*Zeitschr. für Angewandte Chemie*, 1888, p. 699).—The author calls attention to the manufacture of artificial coffee and of machines for that purpose as carried on by certain firms in Cologne. The following analytical results of the artificial product were obtained by O. Reitmair :

	Per Cent.
Moisture,	8·30
Extract soluble in hot water,	34·34
Insoluble organic constituents,	56·26
Inorganic material,	1·10

A microscopic investigation showed that the bulk of the artificial coffee

consists of burnt flour or meal. According to Reitmair, the artificial beans (which are well formed) may be distinguished from the genuine by the fact that the former immediately sink when immersed in ether, while the genuine, on account of the fat contents, float, in great part, on the surface. Furthermore, genuine coffee beans are much more rapidly decolorized by the action of hot, strong oxidizing agents (such as aqua regia or $HCl + KClO_3$) than the artificial. In detecting adulteration of coffee by the artificial article both of these methods of testing should be carried out as preliminary measures. W. C. D.

SALICYLIC ACID FOR PRESERVING EGGS. Lambert (*Arch. de Pharmacie*, 1888, 440).—A solution of salicylic acid is not to be recommended for keeping eggs in preference to lime-water. The acid diffuses through the shell and may be readily detected on the white of the egg. S. C. H.

A GERMAN patent (D. R. P. 45,857) has been granted to A. Doutrelpont, for a process of preparing a new explosive, "Petragit," from molasses. It is an oily nitro-product, and is said to have three times the power of nitroglycerine. S. C. H.

THE ANALYTICAL EXAMINATION OF WATER FOR TECHNICAL PURPOSES. Alfred H. Allen (*Journ. Soc. Chem. Ind.*, **7**, 795).—The results given by the soap test when water contains considerable quantities of magnesium compounds in addition to lime salts are very misleading. A water, containing both lime and magnesia, does not destroy so much soap as the same amounts of lime and magnesia would do separately. The author speaks strongly against further employment of the soap test, unless some means can be found of counteracting the disturbing action caused by magnesium salts. It seems probable that calcium carbonate sometimes exists in a soluble colloid form, which is changed on boiling to the insoluble modification. The author is still investigating the subject. S. C. H.

TRICHLORACETIC ACID is said to be the best and quickest escharotic yet known for warts, corns and bunions (*Merck's Bull.*, 1, **5**, 1888). S. C. H.

HYDROXYCYANIDE OF MERCURY is likely to take the place of corrosive sublimate. It does not attack the metal of surgical instruments, and in some cases shows six times the bactericidal power of corrosive sublimate (*Merck's Bull.*, 1, **5**, 1888). S. C. H.

ON TWO NEW CHLORIDES OF INDIUM, AND ON THE VAPOR DENSITY OF THE CHLORIDES OF INDIUM, GALLIUM, IRON AND CHROMIUM. L. F. Nilson and Otto Petterson (*Ann. Chim. Phys.*, **6**. xv, 545).—The only chloride of indium heretofore known is obtained by heating the metal in an excess of chlorine. According to C. and V. Meyer's determinations of its vapor density, it has the formula $InCl_3$. The experiments of the authors confirm this. By heating indium in a current of dry hydrochloric acid gas a chloride, $InCl_2$, is formed, which, though very stable at high temperatures and when kept dry, is imme-

diately decomposed by water, thus, $3InCl_2 = 2\ InCl_3 + In$. The dichloride, when heated with an excess of In, forms a monochloride InCl, a red substance resembling hematite. This, like $InCl_2$ is decomposed by water, $3InCl = InCl_3 + In_2$. The correctness of the formulæ of both the new chlorides is amply established by their vapor densities. Experiments were also made to ascertain the true formulæ of the chlorides of gallium and chromium, which lead to the acceptance of $GaCl_2$, $GaCl_3$, $CrCl_2$, $CrCl_3$. The so-called sesquichlorides of gallium and chromium must, therefore, in future be expressed by the simpler formulæ, $GaCl_3$,$CrCl_3$. The formula of ferrous chloride, $FeCl_2$, was confirmed.

S. C. H.

RESEARCHES ON COBALT AND NICKEL. Gerhard Krüss and F. W. Schmidt (*Ber.*, **22**, 11).—The authors were engaged in re-determining the atomic weights of nickel and cobalt, by Winkler's method. A weighed quantity of the metal was immersed in a solution of chloride of gold, and the amount of the gold thus expelled determined. In spite of many experiments the results obtained did not agree with the values, as determined by Zimmermann or Winkler, and it was found on closer examination that the precipitated gold contained a small quantity of cobalt (or nickel). In order that this might be removed the precipitate was dissolved in aqua regia, and after the excess of acid had been expelled, the gold was re-precipitated by sulphurous acid. The difference in weight of the gold before and after purification was deducted from the weight of the cobalt (nickel or) taken. Even with this precaution the results obtained were not constant.

On washing gold which had been first precipitated by cobalt, and subsequently by sulphurous acid, it was observed that the last washings were somewhat green. This portion of the filtrate was evaporated to dryness; the residue, after ignition, dissolved on heating in concentrated hydrochloric acid, giving rise to a beautiful green solution, which became almost colorless on cooling. With nickel, the same was observed. The reaction, clearly, was not that of any known substance, and, as in both cases, the amount obtained was extremely small, experiments were started in the hope of extracting larger quantities. This has been successfully accomplished by the authors in several ways.

(1) By repeatedly treating precipitated sulphide of nickel with ammonic sulphide, the nickel was gradually dissolved and the ultimately insoluble residue was found to contain considerable quantities of the desired body.

(2) By crystallizing solutions containing corrosive sublimate and chloride of nickel (or cobalt), the double chlorides separate and the new substance could be obtained from the mother liquor.

(3) By treating the oxides of cobalt and nickel with fused alkalies, the oxide of the new body alone dissolves. In this way about two per cent. of the pure oxide may be obtained from oxide of nickel.

The new oxide gives the following reactions: Ammonic sulphide causes a black precipitate from neutral solutions; ammonia, a white, voluminous precipitate insoluble in excess. The chloride is white when pure, but in contact

with strong hydrochloric acid is greenish. The chloride, but not the oxide, is reduced to a black metal at a red heat.

The following, having reference to the above, is an extract from a letter written by Dr. Krüss, and published in the *Chemical News* of January 25th:

"I have in fact succeeded in splitting up nickel and cobalt each into two parts, and both these metals have one component in common. In concert with my colleague I sent a brief notice on this subject to the *Berichte*, which will appear in Berlin on Monday next (the above is abstracted from this paper here referred to). The matter communicated in this short memoir has been intentionally kept very scanty, and I gave as little room as possible to speculation for fear of being led to assertions which I might, perhaps, soon have to withdraw. Meantime, I have fully confirmed our first observations, and we have now about ten different methods by which we can resolve these bodies, hitherto regarded as elementary, each into two parts. We shall soon give a full report on our results, but in the meantime I may inform you, as a curious fact, that we have succeeded in obtaining *green* so-called nickel salts from *red* cobalt salts and the *colorless* salts of the substance which accompanies both metals, and farther, in transforming some green nickel salts into red cobalt salts and other components. This may sound alchemical, but it cannot be denied. As for the spectra of the three components of cobalt and nickel, we have not yet, with the ordinary experimental arrangements, observed any characteristic lines. This is doubtless the reason why hitherto no spectral lines have been found common to pure cobalt and nickel."

S. C. H.

BOOK NOTICES.

INORGANIC COAL AND LIMESTONE IN AN ELECTRO-CHEMICAL WORLD. By Titus Salter Emery.

A memoir of this character has seldom had a better title than the above. The electro-chemical world, if not the inorganic coal and limestone, are undoubtedly and exclusively by Titus Salter Emery.

In the preface we find that the writer has had a grievance against Prof. J. P. Lesley in reference to some of the measures pronounced by the latter below the lower productive coal series of Pennsylvania, and while the author of this epoch-making pamphlet pays every possible deference and respect to Professor Lesley's descriptive powers and zeal, he proves that the State Geologist was hopelessly wrong in his condemnation of the Tipton Run coal field. So far all is well, but emboldened by the victory over our official geologist, he drops into cosmogony, and the unhappy sub-carboniferous of Blair County must bear the blame of some of the most remarkable statements in physics, chemistry and geology, and some of the boldest conceptions of the genesis of rocks of this or of any age.

The contents of chapter I inform us that "stone coal is a rock, carbon is a metal, all gases are metallic," and, as if these startling statements were

thought likely by the author to too greatly fatigue the mind, he soothes it by the next dictum, that "limestone is a chemical compound," etc.

We have not space or time to follow the statements of this chapter. The usual "most distinguished geologists, chemists," etc., are invoked on all occasions to father statements that would take a good deal of trouble to establish without them. "Like heat, electricity," we are told, "is latent in all matter." "It is a recognized law of chemistry (*sic*) that all matter may be reduced to the gaseous form." "Electricity governs the rotation of the earth upon its axis." "The molecular weight" * * * "is never less than twice the density of the substance in the form of gas." [*Vide* mercury and cadmium.]

"A study of the rocks of Pennsylvania indicates that they are all of *volcanic* origin." "Our most popular geologists claim that limestone is of animal origin," etc. [See Dr. Hunt's Chemical and Geological Essays.] "The almost universal theory of geologists of the highest repute is, that coal, being of vegetable origin, cannot have grown in the agitated waters of the ocean." (!)

"The most noted of our geologists and botanists assert with great positiveness that the carboniferous age has long since passed *its period of greatest luxuriance.*"

"If we assume that among the escaping gases which agitate the surface of the liquid lava *silicon* predominates," etc.

These quotations are more than enough from the work. The conclusions are summed up in the explanation of seven plates, which, by the concluding assertion of the argument of the Mosaic and the geological history, would seem to represent the seven days of the creation. But that day which was taken as one of rest is represented by a plate which is remarkable for its demand on the imaginative power. There are other plates, oo and o, which probably correspond to pre-creative time. The task of reviewing their descriptions or describing their plates is too great. Suffice it to say that the busy worker is now and then solaced by a book of this kind, which lets his pent up volcanic thoughts loose, and doubtless relieves him. Let no one take it too seriously. F.

DEVELOPMENT OF TRANSPORTATION SYSTEMS IN THE UNITED STATES. Comprising a comprehensive description of the leading features of advancement, from the colonial era to the present time, in water channels, roads, turnpikes, canals, railways, vessels, vehicles, cars and locomotives; the cost of transportation at various periods and places by the different methods; the financial, engineering, mechanical, governmental and popular questions that have arisen; and notable incidents in railway history, construction and operation. With illustrations of hundreds of typical objects—by J. L. Ringwalt, Editor of the *Railway World;* Philadelphia, folio, 1888, 446 pages, price $5.

This large and elaborate work, equal to over 1,000 octavo pages, besides forty-eight folio pages of illustrations, is a veritable compendium of facts and data pertaining to all kinds of transportation in the United States, set forth in clear and lucid style. Only by much ability, industry and effort could such a collection have been made and exhibited; it is also the saving of a large amount of important matter from destruction or oblivion. There are refer-

ences to over 1,500 railroads, in the constant mention and discussion of the numerous subjects connected with them and the other modes of transportation. The relations of these systems one to another, and their influence against, or in favor of one another are well set forth ; and the chief features of American railways are shown from their inception to the date of this publication. Extensive and valuable data are given—frequently in tabular form ; and the subjects discussed include, among many others, Early canal financiering, Effects of the completion of the Erie Canal, Cost of canal transportation, Passenger traffic, Early railway financiering, Economic results of early railways, Cost of early freight movements, Effect and extent of reductions of cost of overland transportation, etc.

After the discussion of the ancient modes of transportation on the backs of horses and mules, in rude sleds or wagons drawn by animals, or in arks and on rafts in rivers, much information is given respecting early forms of locomotives, tenders and cars, kinds of flat wrought-iron rails, also ties and sills, together with the failure of stone blocks used instead of ties, and the annoyance and accidents occasioned by the curling up into snags of the ends of flat rails. Accounts of improvements in construction of locomotives, cars, and in management of roads, are rendered in a full and conscientious manner, and their further development traced with precision. This requires a multitude of subjects, among which we can mention only a few, as affording a general idea of the extent of this historical examination—viz : Tunnels, bridges and inclined planes, Rivalry between land and water routes, Position of the competing systems, Railway construction 1830 to 1850, First railway-stock panics, Progress in road and bridge building, Railway supplies, Statistics of constructions and operations 1840, 1850, 1855, 1860, 1870, Consolidation of connecting lines, Operations of trunk lines, Fast freight and express passenger lines, Railways to develop coal regions, Improved grading, Substitution of the cast T-rail for the flat, and of steel for iron rails, Modes of signalling, etc.

While such development is shown in railroads in the earlier and middle period up to 1870, that of the steamboat, at the same time, is as faithfully portrayed. The first forms of the rude attempts at steam navigation are described and illustrated, and there follow the progress in this art from 1840 to 1850, their further improvement up to 1860 and 1870, including the development of passenger and freight steamers for river, lake and coast-wise service, tugboats, steam dredges and the grand trans-Atlantic steamers. In this middle stage, as it might be called, there is some account given of the origin and application of the screw propeller—not, however, as full as desirable ; and the author does not say as much as we thought he would have said, respecting the Baltimore and Philadelphia Steamboat Company (" Ericsson Line "), via the Chesapeake and Delaware Canal, which line (chartered by Maryland, February 23, 1844, and still daily continued) was the first to carry passengers and freight between American cities in vessels having screw propellers. The use of such mode in tugboats commenced five years earlier. This was most important, as developing into the present mode of propulsion of trans-Atlantic steamers. On the latter point there is a considerable amount of information given in this work.

In the period from 1870 to date of publication, denominated "Railway Manhood"—equally so of steam navigation—the historical items and data are very numerous, including much respecting civil and mechanical engineering and mechanical improvements on railways, locomotives, cars and steamers. Prominent notice is given of bridge construction over principal rivers, including wire-suspension bridges, and various descriptions of trusses, with some notable new forms; also the building of tunnels and culverts, railway machine-shops, stations, dépôts and tanks and automatic scoop-troughs for water supply of tenders. Much attention is given in this division to Terminal railway shipping facilities for coal, oil and general merchandise, Increase of varieties of locomotives and cars, Increase of size and power of locomotives and their adaptation to anthracite and slack anthracite coal, Improvement in details of locomotives and general improvements, Capacity of freight cars, Steam brakes and other improvements in car-trucks, wheels and axles, Modes of heating cars, Switches and signals, plain and automatic, and the "block system" along with telegraphic installation for the same, Telegraph communication between stations and between cars in motion, Electric illumination of roads, stations and cars, Iron coal-cars, Grain elevators, Cattle and refrigerating cars, Extensive wharves and facilities for storing and handling coal, Increased mileage of railways, Increase in length of trains and increase in speed of passenger and express trains, Various systems of management, Personnel and legal, traffic and operating departments, Railway relief and insurance associations, etc.

In this and the previous period the rise and progress is noted of the most important pioneer locomotive works such as the Baldwin Locomotive Works, Philadelphia, the Rogers, of Paterson, and others, with honorable mention of the Norris Locomotive Works, of Philadelphia, an establishment now passed away, but useful and eminent in its day. During these two periods the Pennsylvania Railroad Company is well sketched, from its commencement of work in 1849 (sixty-one miles that year) with 102 index references, the New York, Lake Erie and Western with sixty-four, Baltimore and Ohio sixty-seven, Philadelphia and Reading fifty, and several other main roads with twenty to forty-five index references.

In the latter period, though there is less attention given to the development of steamers, there is much respecting the gradual increase in size of vessels and the power of their engines, with more use of high-pressure steam. The vast size and increasing elegance of some passenger steamboats—like those plying on Long Island Sound—is noted, and the gradual improvement of the screw propeller and the wonderful rise of the vast trans-Atlantic lines of steamers, with application of the mixed condensing and high-pressure steam engines, and a constant tendency to increase of size and speed in these vessels.

We are aware that the above is a rather meagre citation from the immense number of subjects included in this really elaborate volume. The more we have examined it, the more we admire the industry, energy and good judgment of the author. As a work intended to assist the future historian too much praise cannot be given; but it also directly interests a

large class of business men, such as merchants, bankers, journalists, lawyers, legislators, railway directors and operators, civil and mechanical engineers, students of economic science, etc. All these will find much of interest in this history, and, possibly, what may prove of great value in legal questions.

The illustrations form a valuable portion of this work. Of them there are forty-eight pages, a few containing two, but the most six to twelve designs, showing graphically the first rude wagons, arks, canal boats, steamboats, locomotives, cars, bridges and trestle work. Next are exhibited similar but vastly improved forms, including the T cast-iron rail, of several descriptions, and finally magnificent locomotives and palace cars of the present day, immense river steamboats and Atlantic steamers, powerful tug and ice boats, improved forms of light-houses, etc. A number of maps show the railroad system of the United States. A full index of railways and a general index close the volume. In glancing over these their value will be appreciated, and it will be seen that the above citations of subjects have been comparatively small in number. We cordially recommend this excellent compendium of transportation history and literature, and wish for it the wide circulation in the United States, Canada and Europe which it so well deserves. One thing is certain, it is destined to become a standard work of reference. N.

MICROSCOPICAL PHYSIOGRAPHY OF THE ROCK-MAKING MINERALS AND AN AID TO THE MICROSCOPICAL STUDY OF ROCKS. By H. Rosenbusch. Translated and arranged for use in schools and colleges, by Joseph P. Iddings. Illustrated by 121 wood-cuts and twenty-six plates of photomicrographs. New York: John Wiley & Sons, 15 Astor Place.

This is a very important and much needed work. It places the student who cannot read German, for the first time in several years in a position abreast of the times; for to prosecute micro-mineralogy without Rosenbusch is like studying law without Blackstone, or (a better simile would be) without the record of modern cases. The work is a great improvement on Rosenbusch's first edition of 1873, and, for the practical student, even of that of 1885. The English is an abridgment of the German work, yet the portions cut out are not such as to mar in any way the usefulness of the book to the English or American student.

As stated by the translator in his preface, the omissions are chiefly of the historical matter, and of the thorough discussion of the optical anomalies of certain minerals. The nomenclature and the method of Prof. Rosenbusch are preserved, except in the first named three or four words, for which there was good reason to retain the forms generally current in American petrological literature.

In the first or general part of the book, after a few words on the preparation of the material for examination, which might, with advantage, have been extended, the main subjects rendered familiar by Rosenbusch's treatment are taken up, and in clear and scientific English are laid before the reader.

The print and paper are excellent (as is usual with Wiley's scientific publications), and the twenty-six plates of micro-photographed figures are

admirably chosen for illustration, and generally good as specimens of printing. F.

THE "LAKE SUPERIOR COPPER PROPERTIES," ETC. By Henry M. Pinkham.

This is a handy little pamphlet of 102 pages, which gives a great deal of valuable information concerning the copper properties of the Lake Superior district, but arranged statistically and following a natural order, without invoking the nebular hypothesis and the prophetic imagination. It is accompanied by a skeleton sketch map, on which the approximate positions of the chief copper mines are set down. It treats of the districts in the order in which they were known as copper districts by the public, viz: Keweenaw, Ontonagon and Houghton.

The concluding three pages are devoted to excerpts from the report of President Clark and Treasurer Bigelow in the last annual report of the Tamarack Mining Company, taking strong ground in favor of the course of controlling all the great mines of the world, to secure their "well being," because "the stimulus of present prices will necessarily lead all parties to crowd to their utmost all their energies in the line of production, and if this output is thrown upon the market without control, it will surely result in disaster, while under the present ownership and management it will not be difficult to compel an equitable distribution."

It is a necessity to all those who are interested either in mines in Michigan or in copper. F.

BULLETIN NO. 5, OF THE STATE COLLEGE AGRICULTURAL EXPERIMENT STATION. October, 1888.

This little pamphlet of eleven pages, by William Frear, Vice-Director and Chemist, is devoted to a treatise of the digestibility of soiling rye, giving the plan of experimentation and comparison with other fodders. The coefficients of digestibility of the material fed to two steers form the concluding lines of an interesting table, and will surprise the non-professional agricultural chemist by the closeness of agreement of the results of these processes in Nature's laboratories—the animal stomachs.

The whole paper is interesting and illustrates the importance of liberally endowing these scientific establishments of the state. F.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Academie Royale des Sciences de Belgique. Annuaire. 1889.
From the Academy.

American Institute of Mining Engineers. Twenty-four Reprints.
From the Institute.

American Pharmaceutical Association. Proceedings. Thirty-sixth Annual Meeting.
From the Association.

American Philosophical Society. Proceedings. No. 128.
Rules and Regulations Magellanic Premium.
Rules and Regulations Henry M. Phillips Prize Essay Fund.
Supplementary Report of the Committee appointed to Consider an International Language. From the Society.

Baltimore, Md. Weekly Mortuary Reports. 1888.
From the Health Department.

Bay City, Mich. Report of the Superintendent of Water Works, for 1886 and 1887. From the Water Department.

Bergman, M. T. Opuscules Chimiques. From Mr. R. A. Fisher.

Board of Commissioners of Electrical Subways. New York. Third Report.
From Mr. Schuyler S. Wheeler.

Board of Electrical Control, New York. First Report.
From Mr. Schuyler S. Wheeler.

Boston Public Library. Bulletin No. 78. From the Library.

Brass. From Messrs. B. H. & H. Cramp.

Brown, H. P. The Comparative Danger to Life of the Alternating and Continuous Electrical Currents. From the Author.

Bureau of Education. Report of the Commissioners for 1886–87.
From the Bureau.

Bureau of Statistics. Quarterly Report of the Chief. No. 1. 1888–89.
From the Bureau.

Bureau of Steam Engineering. Annual Report of the Chief for 1888.
From the Bureau.

Canada. Tables of the Trade and Commerce. 1888.
From Mr. G. H. Fawcett, Customs Department, Canada.

Canadian Archives. Report for 1888. From the Minister of Agriculture.

Catlin, Benj. R. Report on the Validity and Character of Certain Patents Granted to Henry C. Rew. From Henry C. Rew, Esq.

Chief Signal Officer, U.S.A. Annual Report. 1887. Part 2.

Comptroller of Currency, U. S. Annual Report. 1888. Vol. 1.
From the Comptroller.

Connecticut Agricultural Experiment Station. Bulletin No. 96.
From the Station.

Corps of Royal Engineers. Occasional Papers. Vol. 13.
From the Royal Engineers' Institute.

Deane's Manual of Fire Arms. From Mr. R. A. Fisher.

District of Columbia. Report of the Board of Trustees of Public Schools. 1887–88. From the Board.

Engineer Department, U.S.A. Annual Report of the Chief of Engineers. 1888. Parts 1 to 4. From the Department.

Engineers Society of Western Pennsylvania. Paper read December 18, 1888.
From the Society.

Greely, A. W. International Polar Expedition. Report of the United States Expedition. Vol. 2. From the Author.

Griffing Iron Company. Illustrated Catalogue. 1886–87 and 1888–89.
From the Company.

Halifax, Nova Scotia. Municipal Reports. 1876–77, 1877–78, 1878–79, 1887–88. From the City Clerk.

Hunt, R. W. Steel Rails and Specifications for their Manufacture. From the Author.

Hydrographic Office, U. S. Pilot Chart of the North Atlantic Ocean. February, 1889. From the Office.

Indiana. State Librarian Biennial Report for 1887 and 1888. From the Librarian.

Instituto y Observatorio de Marina de San Fernando. Anales. Ano 1887. From the Observatory.

Iowa. Legislative Documents Submitted to the Twenty-second General Assembly. January, 1888. Vols. 1–5. From the Secretary of State.

Johnson's Graphic Statistics of Canada. From Mr. G. H. Fawcett, Customs Department, Canada.

Klein, J. F. Tables for Laying Out Accurate Profiles of Gear Teeth. From Mr. E. G. Klose, Bethlehem.

Lavoisier, M. Traité Elémentaire de Chimie. From Mr. R. A. Fisher.

Light-House Board, U. S. Annual Report for 1888. From the Board.

Manual of Anthracite Coal Statistics. Compiled and Presented by Bureau of Anthracite Coal Statistics. Philadelphia, 1888.

Marks, A. A. A Treatise on Artificial Limbs. From the Author.

Master Car Builders Association. Reports of the Proceedings of the Twelfth to Seventeenth, and Nineteenth to Twenty-second Annual Convention, held 1878 to 1883, and 1885 to 1888.

History and Early Reports of the Association, Including the First and Sixth Annual Reports for the years 1867 to 1872.

Report of the Proceedings of an Adjourned Meeting, held at Niagara Falls, October, 1882.

Report to the Association by the Committee on Automatic Freight Car Brakes. 1887.

Code of Rules Governing the Condition of and Repairs to Freight Cars for the Interchange of Traffic. Revised. June, 1888. From M. N. Forney, Secretary.

Mercantile Library of Philadelphia. Bulletin No. 26. From the Library.

Michigan State Board of Corrections and Charities. Ninth Biennial Report. 1887–88. From the Board.

Milwaukee, Wis. Department Reports. 1884 to 1887. From the City Comptroller.

Minnesota. Geological and Natural History Survey. The Geology of Minnesota. Vol. 2 of the Final Report. From the State Geologist.

New Jersey. Adjutant-General's Report for they ear ending October 31, 1887. From the State Historical Society.

New Jersey Agricultural Experiment Station. Bulletin No. 51. From the Station.

New Jersey Archives. General Index to the Documents Relating to the Colonial History of the State. First Series, in Ten Volumes.

New Jersey. Board of Commissioners of Pilotage. Annual Report for the year ending October 31, 1887.

Boundary Commission, Report and Proceedings of the, appointed to Locate and Mark Out, by Stakes and Buoys, the True Boundary Lines between New York and New Jersey in Lands under Water in Raritan Bay.

Comptroller of the Treasury. Annual Report for the year ending October 31, 1887, with Abstracts of the Amount of Ratables, etc.

Dairy Commissioner. Report for 1887.

First Annual Message of Robert S. Green, Governor of New Jersey, to the Legislature. Session of 1888.

Geological Survey. Annual Report of the State Geologist for 1887.

Inspector of Factories and Work-shops. Fifth Annual Report for 1887.

Report of the Gettysburg Battle-field Commission of New Jersey, dated December 15, 1887.

Report of the Joint Committee on Treasurer's Accounts to the Legislature of New Jersey, with the Treasurer's Report on the Finances for year ending October 31, 1887.

Riparian Commissioners. Annual Report for year ending 1887.

State Asylum for the Insane, at Norristown. Twelfth Annual Report for 1887. From the State Historical Society.

State Board of Assessors. First to Fourth Annual Reports. 1884–87. From the Board.

State Board of Pharmacy. Annual Report for year 1887.

State Normal Schools. Thirty-third Annual Report of the Board of Trustees, etc., for year ending June 30, 1887.

Report of Rutgers Scientific School, the State College, for 1887.

State Lunatic Asylum at Trenton. Annual Reports for year 1887. From State Historical Society.

North Carolina. State Librarian Second Biennial Report. January 1, 1889. From the Librarian.

Patent Office, U. S. Specification and Drawings. January, 1888. From the Office.

Pennsylvania Academy of Fine Arts. Catalogue of the Fifty-ninth Annual Exhibition. From the Academy.

Pennsylvania State College. Agricultural Experiment Station. Bulletin No. 6. From the College.

Philadelphia Gas Works. 27, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 41, 42, 43, 52. Annual Reports of the Trustees. January 1862 to 1887. From Mr. J. E. Salter, President.

Philadelphia Mayor's Message. First Annual Message of Edwin H. Fitler. 1887. Vols. 1 to 4. From Hon. E. H. Fitler, Mayor.

Philadelphia Health Officer's Annual Report for the year 1886, and Annual Report of the Bureau of Health for 1887.
From Mr. Joseph G. Patterson, Health Officer.

Price, L. Manual of Photographic Manipulations.
From Mr. R. A. Fisher.

Public Ledger Almanac. 1889. From Mr. Geo. W. Childs.

Putnam, Israel. History of the Equestrian Statue of.
From the Connecticut State Library.

St. Louis. Ninth Annual Report of the Health Commissioner. 1884–85.
From the Commissioner.

San Francisco Health Department. Annual Reports for years ending June 30, 1878, 1881 and 1882.
Condensed Statements of Mortalities for August and December, 1888.
From the Department.

Schouw, J. F. Earth, Plants and Man. From Mr. R. A. Fisher.

Signal Office, U.S.A. Daily International Chart. November, 1887.
Summary and Review. November, 1887. From the Office.

Smithsonian Institution. Report on International Exchanges.
From the Institution.

State Board of Health of Pennsylvania. Third Annual Report.
From the Board.

State Department, U. S. Reports from the Consuls of the United States. September and October, 1888.
From Dr. Wm. H. Wahl.
Reports from the Consuls of the United States. September to December, 1888.
From the Department.

Stewart, Wm. M. Money Answereth All Things. Speech in the Senate of the United States. From the Hon. Wm. M. Stuart.

Sylvén, Theodor Walfrid. Improvements in the Construction of Steamships and Rudders. From the Author.

Texas. A Partial Report on the Geology of Western Texas, and a Journal of Geological Observations along the Routes Travelled by the Expedition between Indianola, Tex., and the Valley of the Mimtres, during 1855 and 1856, etc. By Prof. Geo. G. Shumard.
From the Commissioner of Insurance, Statistics and History.

Toledo, O. Annual Reports of the Board of Health for 1869, 1870, 1878, 1880, 1881, 1882, 1883, 1884, 1886, 1887.
Report of the Police Board for 1887.
From the Board of Health.

U. S Department of Agriculture. Divison of Entomology.
Periodical Bulletin No. 7.
Report of the Statistician No. 58.
From the Department.

United States Geological Survey. Bulletin Nos. 40 to 47.
Mineral Resources of the United States, 1887. From the Survey.

United States Mint. Report of the Director on the Production of Precious Metals. 1887. From the Director.

Virginia. Acts of Assembly, 1885–86; Extra Session, 1887, 1887–88.
Senate Journal, 1885–86; Extra Session, 1887 and 1887–88.
House Journal, 1885–86; Extra Session, 1887 and 1887–88.
Annual Reports of Officers, Boards and Institution. 1885, 1886 and 1887. From the Secretary of State.

Willard, De Forest. Osteotomy for Anterior Curves of the Leg. From the Author.

Wisconsin. Academy of Sciences, Arts and Letters. Transactions. Vol. 6, 1881–83.
Blue Book. 1887.
Bureau of Labor and Industrial Statistics. Third Biennial Report. 1887–88.
From the State Historical Society of Wisconsin.
Farmer's Institute, 1887. Bulletin No. 1.
From Director Agricultural Experiment Station.
Governor's Message and Accompanying Documents. 1883 and 1885. Vols. 1 and 2. From the Secretary of State.
Laws of Wisconsin, except City Charter, etc. 1883, vol. 1; 1885 vol. 1. From the Secretary of State.
Insurance Commissioner's Second and Third Biennial Reports for 1885–86, 1887–88.
Insurance Laws, 1878–88. From the Commissioner.
Laws of 1887. Relating to Public Schools.
From the State Superintendent.
Normal Schools. Annual Report of the Board of Regents for 1879–80. Biennial Report for 1884–85, 1885–86 and 1886–87, 1887. From the Board.
Railroad Commissioner. Second Biennial Report. 1885–86.
From the Commissioner.
Roster of Wisconsin Volunteers. War of the Rebellion. 1861–65. Vols. 1 and 2. From the State Historical Society.
State Agricultural Society. Transactions. Vols. 25 and 26. 1887 and 1888. From the Society.
State Board of Health. Tenth and Eleventh Reports. 1886 and 1887.
From the State Historical Society of Wisconsin.
Dairymen's Association. Eleventh, Twelfth, Thirteenth and Sixteenth Annual Reports, for 1883, 1884, 1885 and 1888.
From the Association.
State Historical Society. Catalogue of the Library. Vol. 7 (Fifth Supplement). Biographical Sketches of Lyman C. Draper and Mortimer Melville Jackson. Madison. 1887.
Early Days in Jefferson County. By Elisha W. Keyes.
History of the Public Schools, of Madison, Wis. By Reuben G. Thwaites.

Local Government in Wisconsin. By David E. Spencer.

Pre-historic Wisconsin. By Prof. James D. Butler. Westphalian Medal. 1648. By J. D. Butler.

Reminiscences of Morgan L. Martin. 1827–87. Edited and Annotated, with a Biographical Sketch. By Reuben G. Thwaites.

The Boundaries of Wisconsin, with a General Historical Survey of the Division of the Northwest Territory into States. By Reuben G. Thwaites.

The Influence of History on Individual and National Action. By Paul A. Chadbourne. From the Society.

State Horticultural Society. Transactions for 1887. From the Society.

State Medical Society. Transactions. 1869, 1870, 1871, 1875, 1876, 1880, 1881, 1882, 1883, 1884, 1885 and 1888. From the Society.

State Superintendent [of Schools]. Biennial Reports. 1885–86, 1887–88. From the Superintendent.

University of Agricultural Experiment Station. Bulletin No. 3. June, 1884. From the Station.

Yonkers, N. Y. Municipal Reports. 1883–84 to 1887–88, inclusive. From the City Clerk.

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, February 20, 1889.*]

HALL OF THE INSTITUTE,
PHILADELPHIA, February 20, 1889.

JOSEPH M. WILSON, President, in the Chair.

Present, 119 members and nine visitors.

Additions to membership since last report, seventy-nine.

The Chairman of the Special Committee to Increase Membership made a report of progress.

Mr. F. LYNWOOD GARRISON exhibited a series of handsome specimens of artistic metal work made in Russia, and made some explanatory remarks respecting the same, and on the state of artistic metal working in Russia.

Dr. E. S. McCLELLAN, of Paterson, N. J., presented a communication descriptive of a method and apparatus for automatically preventing the unsealing of house drainage traps by siphoning. A working model was shown, exhibiting the construction and operation of the invention.

The report of the Secretary contained reference to the forthcoming International Exhibition in Paris, and a comparative description of the Electric Reduction Processes of Messrs. Cowles and M. Herault.

Adjourned, WM. H. WAHL, *Secretary.*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F. M. Thorn Superintendent
Comparative Map
showing changes of shore line at
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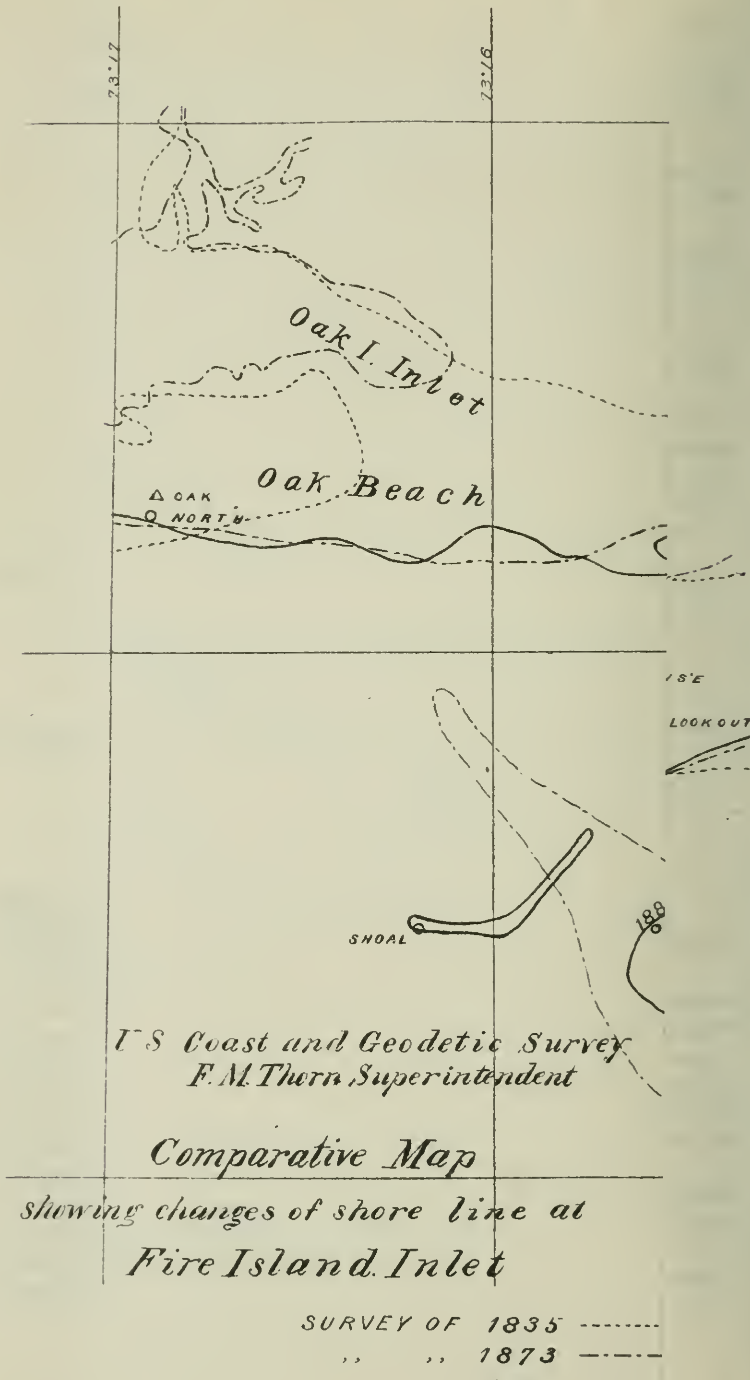
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U S Coast and Geodetic Survey
F. M. Thorn Superintendent
Comparative Map
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SURVEY OF 1835
" " 1873
" " 1887

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVII. APRIL, 1889. No. 4.

FIRE ISLAND INLET.

IS IT MOVING EAST OR WEST, AND AT WHAT RATE?

BY LEWIS M. HAUPT.

In a recent discussion before the Committee on Science and the Arts relative to the comparative effects of wind *vs.* tide in producing changes along the alluvial coasts and at harbor entrances of the United States, the writer supported the theory that the resultant direction of the natural forces acted in certain definite directions at various parts of the coast and that these directions conformed in general to those of the flood tide, and were not due chiefly to prevailing winds, as is generally supposed.

In support of this theory numerous instances were cited, and amongst others the westward progression of the spits and inlets on the outer or south shore of Long Island.

On the other hand, it was urged by a member of the committee that the theory was inconsistent with the fact, and Prof. Henry Mitchell, of the U. S. Coast and Geodetic Survey, was quoted as saying that

"The motion of the waves is not always in the direction of the prevailing winds. * * * An example of this is shown by the action of the waves on the north side of Long Island, N. Y., which drifts the material westward, while on the south side the motion of the drifted material is eastward, and yet the prevailing winds must be the same on the two sides of the island."

The above paragraph was quoted, not to show that the winds did not always blow from the right quarter, but that Professor Mitchell was authority for the statement that the *drift on the south side of Long Island is eastward*, whereas the theory the writer supported required it to be westward. There was produced, also, a coast survey chart of Fire Island Inlet to demonstrate the alleged fallacy of this theory.

At this point the discussion was terminated abruptly, leaving erroneous impressions detrimental to scientific truth, and showing the danger of generalizing from special cases.

What Professor Mitchell states is true, but only for a limited portion of the eastern end of the island, where, during the entrance of the flood tide into the sound, a draft current is produced around Montauk, but for nearly the entire length of the shore line the movement is westerly, as stated. To leave no doubt as to this point, as well as to show the errors liable to arise from comparing the relative volumes of the sand-bars on either flank of a navigable channel, an official copy was obtained from the U. S. Coast and Geodetic Survey Office, of the comparative surveys of the point in question for the years 1835 to 1873 and 1887, showing some definite yet not unusual features. The accompanying chart reduced therefrom needs but little interpretation, for it is seen at once that during the fifty-two years, from 1835 to 1887, the eastern point of Fire Island Beach has advanced westerly about 9,960 feet, or nearly two (2) miles. The

average rate was 186 feet per annum, which is about the same as that on the Texas coast near Aransas Pass. From 1835 to 1873 the movement was at the rate of 170 feet, and during the later period of fourteen years, it was about 220 feet each year. Or if the distance be taken to the western end of the island, now forming in the inlet, it will give about 12,000 feet in fifty-two years, an average of say 230 feet. The general direction of the shore line remains at S. 75° W.

The changes on the inner or receding beach clearly indicate a filling up of the lateral inlets and corresponding progression of the western spit. This filling occurs in lee of the shelter afforded by the overlapping seaward hook, where the sand, which has been travelling westwardly along the outer beach, finds a comparatively quiescent basin into and across which it is carried by the action of both flood and ebb currents, only to renew its journey along shore under the transporting agency of the flood waves.

To remove all doubt as to the facts in the case, the writer addressed a letter to the Hydrographic Office, requesting information from competent observers along this coast. In consequence, the annexed circular was sent to the keepers of the Life-Saving Stations, from a few of whom replies have been forwarded through the courtesy of the office.

SIR:—The Hydrographic Office is desirous of obtaining all possible data regarding the movement of wreckage and other bodies along the shore as affected by wind, waves, currents and tides. This information is desired with special reference to the action of tidal and other currents immediately adjacent to the coast line, with a view of its utilization in considering the formation of bars and the shifting of the coast line at the entrance to our rivers and harbors.

Will be thankful for any information you can furnish on this subject at your earliest convenience.

Shall always be glad to serve you at any time, and hope you will do me the honor of calling upon me, when the occasion arises. I am,

Very respectfully,

[Signed] V. L. COTTMAN,

Lieut. U. S. Navy, in charge.

Although this letter was sent to forty-five stations, replies have been received from but eight.

EXTRACTS FROM REPORTS OF LIFE-SAVING STATION KEEPERS OF THE THIRD U. S. LIFE-SAVING DISTRICT.

Latitude, 40° 47′ 30″.
Longitude, 72° 39′ 00″.

PETUNK STATION, N. Y., January 10, 1889.

"In moderate weather, with small sea, the current changes with each turn of the tide, running west longer than east. From August to May much the heaviest amount of current runs west. During the summer months it runs each way more equally. Heavy wreckage from stranded vessels moves much more west than east. Outlets from all bays along this coast move west. The shore line is slowly working on to the land. About three months after the steamship *City of Columbus* was wrecked at or near Gay Head (west end of Martha's Vineyard), one of her life preservers, made of ground cork and thoroughly water-soaked, was picked up near this station. Part of a schooner, with the official number, that went to pieces inside of Montauk, came ashore here."

[Signed] FRANKLIN C. JESSUP,
Keeper Petunk Life-Saving Station.

Latitude, 40° 35′ 30″.
Longitude, 73° 47′ 20″.

ROCKAWAY STATION, January 4, 1889.

"The currents along the shore here are generally to the west, and the formation of bars are most always shifting from east to west. Wreckage and all substances which are carried by currents are most always carried west. Inlets and shoals are always shifting to the west. Of course, there are exceptions to this, such as heavy west winds, when the current will, for the time, run to the east, but as far as my experience goes the currents are from the north and east to the south and west along the coast.

"I have known a good many wrecks along this coast, and the wreckage would go to the west, but I never 'knowed' of it going to the east.

"The wreckage of the steamship *Oregon* was found as far

south as North Carolina, but I never heard of any being found east, and some years ago there was a schooner ashore east of Fire Island, loaded with cotton. When the wreck broke up the cotton came west as far as this station and to the west of it." *

[Signed] WM. H. REINHART,
Keeper.

Latitude, 40° 34′ 10″.
Longitude, 73° 51′ 50″.

ROCKAWAY POINT STATION, L. I., January 17, 1889.

LIEUT. V. L. COTTMAN, U. S. N.

SIR:—Your circular asking information of wreckage and other bodies along shore is received.

If deeply submerged in the water, ebb tide will carry them east, while flood tide will carry them west. A light substance will float according to the wind. All inlets and shoals work or form to the westward.

[Signed] Respectfully, D. B. ABRAMS,
Keeper.

Latitude, 40° 34′ 20″.
Longitude, 73° 56′ 20″.

CONEY ISLAND L. S. STATION, Manhattan Beach,
January 15, 1889.

LIEUT. V. L. COTTMAN.

SIR:—Yours of the 2d received. * * * About four years ago the sloop *Undine*, while coming in Rockaway Inlet, shipped a sea and sunk. She was at the time on the edge of the east shoals. After about eighteen hours she drifted W. by N. W. (nearly half a mile). Here she laid about stationary for eighteen hours, and then in twelve hours' time reached a point 100 yards S. E. from east end of Manhattan Beach Bulkhead. She dragged bottom the whole of the distance.

A large hawser was lost off a steamboat near where the *Undine* sank (Main Rockaway Inlet), and after about six months came ashore about 300 yards east of Manhattan

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* This would be from thirty-five to forty miles.

Beach Bulkhead. * * * Rockaway Beach has been steadily gaining ground to the west. The gain for the last twenty years has been about four miles.

[Signed] R. H. RYDER,
Keeper.

Thus in this range of 1° 17′ of longitude, equivalent, at this latitude, to about sixty-eight miles along the southern coast of Long Island, there is found to exist a progressive westerly movement of the shore line, corresponding to the direction of the bottom currents during the incoming tide. If the rate of growth of Rockaway Beach is correctly stated, it would indicate a more rapid movement, as the tide is compressed towards the gorge at the entrance to New York Bay, between Coney Island and Sandy Hook. From this it would appear that the westerly movement of the beach sand is due chiefly to the direction of the flood tide, rather than to the alleged prevailing direction of the wind or to northeast storms, which here would be off shore.

THE TRANSMISSION OF POWER BY ELECTRICITY.

FRANK J. SPRAGUE.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 12, 1888.*]

(*Concluded from Vol. cxxvii, page 176.*)

In considering the transmission of power, some very curious and valuable facts may be demonstrated by a formula for determining the minimum cost of plant, where the amount of power at the generating station is practically not limited, and where there is no line loss from leakage, the line loss being measured simply by the fall in potential.

The cost of a plant of this character can be divided into five parts, that of the motors, the conductors, the line erection, the dynamos, and the power plant, whether water or steam. I will assume that the cost of the dynamos and

motors is the same per horse-power or other unit, no matter what the electro-motive force used. While this is not strictly true, for all practical purposes, with large units, and speaking from the commercial standpoint, it can be so assumed. This being the case, for any given power the cost of the motor is a constant, independent of the potential used. With any given motor potential, the greater the loss on the line, the less the cost of the conductors, but the greater the cost of the generators. On the other hand, the less the loss on the line, the greater its cost, but the less the cost of the generating plant. It follows, then, that the least cost to the contractor is determined when the variation in the cost of the generator is equal to that in the cost of the line, and it is to a consideration of this fact that I wish to call your attention:

We have the formula

$$C\,M = \frac{1492\,n\,m\,l}{E\,v\,a}$$

Let d equal weight of one mil-foot of copper. Then the weight per foot of the copper of our conductor would be

$$\frac{1492\,n\,m\,l\,d}{E\,v\,a} \tag{3}$$

and the total weight for $2\,l$ would be

$$\frac{2984\,n\,m\,l^2\,d}{E\,v\,a} \tag{4}$$

If b is the cost in cents per pound of copper (the cost of insulation being added to cost of copper), we have for the cost of the wire in the line

$$\frac{2984\,n\,m\,l^2\,d\,b}{E\,v\,a} \tag{5}$$

It is to be noted here that this cost b must be expressed so much per pound of copper. It may be that we have a line covered by an insulation of such character that for every dollar's worth of copper there may be \$3 or \$4 worth of insulation. For example, suppose that a $^1/_0$ B. W. G. wire

be used, covered with an insulation that should make it cost say $150 a thousand feet. The actual weight of copper in the line would be only 350 pounds, which, at $150 market price, would make the wire cost forty-three cents per pound of copper. It is this cost, plus the cost of freight and handling, which must be used as the value of b.

Let E equal the E. M. F. at the terminals of the motor; e, the motor electro-motive force; v, the fall of potential on the line; β, the commercial efficiency of the dynamo; E'', the E. M. F. of the generator, and n the number of H. P. developed by the motor. Then we have evidently

$$\frac{e}{E''}$$

as the ratio of the watt capacity of the motor and generator;

$$\frac{n}{a}$$

the H. P. of electrical energy delivered at the motor terminals;

$$\frac{E+v}{E} \times \frac{n}{a}$$

the H. P. of electrical energy delivered to the line, and

$$\frac{E+v}{E} \times \frac{n}{a} \times \frac{1}{\beta}$$

that delivered to the generator.

I think it advisable to make use of the term horse-power and commercial efficiency, for it is partly from the commercial aspect I wish to look at the problem, and it is the side which in business we must confront.

Let us further make K equal the cost in cents of the generators per horse-power required to drive them, and L the similar cost per horse-power of the steam or water plant, all of course erected in place, that is with the cost of freight, handling, insurance, and erection added to the factory or shipping cost. Then the cost per horse-power of the generating plant complete would be:

$$\frac{E+v}{E\,a\,\beta}\,n\,(K+L) \tag{6}$$

If M is the cost of motor per horse-power developed similarly erected in place, the cost of the receiving plant would be $n\ M$.

We now have one element which is somewhat indeterminate and is dependent chiefly upon distance and local conditions, and that is the cost of pole and line erection, and we will call this P.

Summing up our cost we have the general expressions for the cost per horse-power delivered :

$$C = \frac{E + v}{E\ a\ \beta}\ (K + L) + \frac{2984\ m\ l^2\ d\ b}{E\ v\ a} + M + \frac{P}{n} \qquad (7)$$

It is evident that this is variable, and since the costs of the motor and the line erection are arbitrary, the variation is narrowed down to the cost of the generating plant and the material in the line. It is here apparent, as already pointed out, that if we diminish the cost of the line by increasing the fall of potential, we must at the same time increase the cost of the generating plant, and on the other hand, that if the loss on the line is reduced, its cost will increase, while that of the generating plant will diminish.

Differentiating with v as the variable, we have,

$$\frac{d\ c}{d\ v} = \frac{K + L}{E\ a\ \beta} - \frac{2984\ m\ l^2\ d\ b}{E\ a\ v^2} \qquad (8)$$

or equating to zero

$$\frac{K + L}{\beta} = \frac{2984\ m\ l^2\ d\ b}{v^2} \qquad (9)$$

which is the condition of least cost.

From (9) we have

$$v = 54{\cdot}6\ l\ \sqrt{\frac{m\ d\ b\ \beta}{K + L}} \qquad (10)$$

That is, with fixed conditions of cost and efficiency of apparatus, the number of volts fall to get the minimum cost of plant is a function of the distance alone and is independent of the electro-motive force used at the motor, a somewhat startling conclusion.

Substituting the equivalent value given by equation (9) in (7) we now have for the equation of least cost,

$$C = \frac{E + v}{E\,\alpha\,\beta}(K + L) + \frac{v}{E\,\alpha\,\beta}(K + L) + M + \frac{P}{n} \qquad (11)$$

The first element representing the cost of the generating plant and the second the cost of the wire per the horse-power developed by the motor. The cost of the wire is given as a ratio of the cost per horse-power of the generating plant. From this equation we have the relation:

$$\frac{\text{Cost of wire}}{\text{Cost of generating plant}} = \frac{v}{E + v} \qquad (12)$$

This is not, however, in a very useful form, and since the commercial efficiency is that with which we are concerned, we will introduce a term, designating it λ.

We have for the H. P. delivered to the generator,

$$\frac{E + v}{E\,\alpha\,\beta}n$$

and n that taken out of the motor; hence we have,

$$\lambda = \frac{E\,\alpha\,\beta}{E + v} \qquad (13)$$

or

$$v = \frac{\alpha\,\beta - \lambda}{\lambda}E \qquad (14)$$

Substituting the value of v in equation (11), we have a new form of the cost equation as follows:

$$C = \frac{K + L}{\lambda} + \frac{\alpha\,\beta - \lambda}{\alpha\,\beta\,\lambda}(K + L) + M + \frac{P}{n} \qquad (15)$$

a still simpler formula. We also have the relation,

$$\frac{\text{Cost of wire}}{\text{Cost of generating plant}} = \frac{\alpha\,\beta - \lambda}{\alpha\,\beta} \qquad (16)$$

That is, *with any fixed couple and commercial efficiency, the cost of the wire should bear a definite and fixed ratio to the cost of the generating plant.*

But the query arises at once, is this so, no matter what the cost of the copper? And the answer is an affirmative one, and why this is so will soon be apparent.

Referring to the equation (10) and substituting for m its approximate value, 10·5, and for d its value, ·00000302705, we have:

$$v = \cdot 308\, l \sqrt{\frac{b\, \beta}{K + L}} \tag{17}$$

Combining this with (13), we find that

$$E = \frac{\cdot 308\, l\, \lambda}{a\, \beta - \lambda} \sqrt{\frac{b\, \beta}{K + L}} \tag{18}$$

We now see what influence the cost of copper has when the commercial efficiency is maintained constant, which is to vary the value of E as it increases, but only as the square root of such increase. It will be noticed also that a variation in $K + L$ inversely affects E and v likewise as the square root.

It follows from the above that if we do not limit ourselves in the E. M. F. used, the cost per H. P. delivered exclusive of line erection, is, for least cost and for a given commercial efficiency, absolutely independent of the distance.

We are met at times with the condition that the motor potential shall not be above a given amount, and from the formula,

$$E = \frac{\cdot 308\ l\ \lambda}{a\, \beta - \lambda} \sqrt{\frac{b\ \beta}{K + L}}$$

transposed to

$$\lambda = \frac{E\ a\ \beta}{.308\ l \sqrt{\frac{b\ \beta}{K + L}} + E} \tag{19}$$

we find at once what the efficiency of the transmission must be with a given distance, and therefore whether it is worth while to attempt the operation. On the other hand, if, for example, we make our lower limit of commercial efficiency 50 %, $a\ \beta =$ 80 %, and $\beta =$ 90%, we have a limiting equation.

$$E = .487\ l \sqrt{\frac{b}{K + L}} \tag{20}$$

Since the circular mils vary inversely with $E\ v$, the size,

weight and cost of the wire vary directly as the cost of the generating plant, which we have already seen from another formula. To get a matter-of-fact idea of this, I will assume some values, as follows:

Let $K = \$45.00$, $L = \$20.00$ (say for a water-power), $M = \$50.00$, and $b = 25$ cents for copper delivered on the ground.

Then we would have our formulæ for this particular case reduced to the following:

$$v = \frac{4 - 5\lambda}{5\lambda} E \tag{21}$$

$$v = .0181\, l \tag{22}$$

$$E = \frac{.0905\,\lambda}{4 - 5\lambda}\, l \tag{23}$$

and

$$\lambda = \frac{4\,E}{5\,E + \cdot 0905\, l} \tag{24}$$

which will give us the required elements of any single transmission under these conditions.

For example, suppose we wish to transmit 20,000 feet. The fall of potential on the line could be 362 volts, and this is independent of the commercial efficiency. If this latter is made, say sixty per cent., then $E = 1{,}086$ volts, and the potential at the terminals of the generator should be 1,448 volts. On the other hand, suppose we want to transmit a distance of 10,000 feet with a motor terminal potential of 800 volts, then $\lambda = 65$ per cent., and $v = 181$ volts.

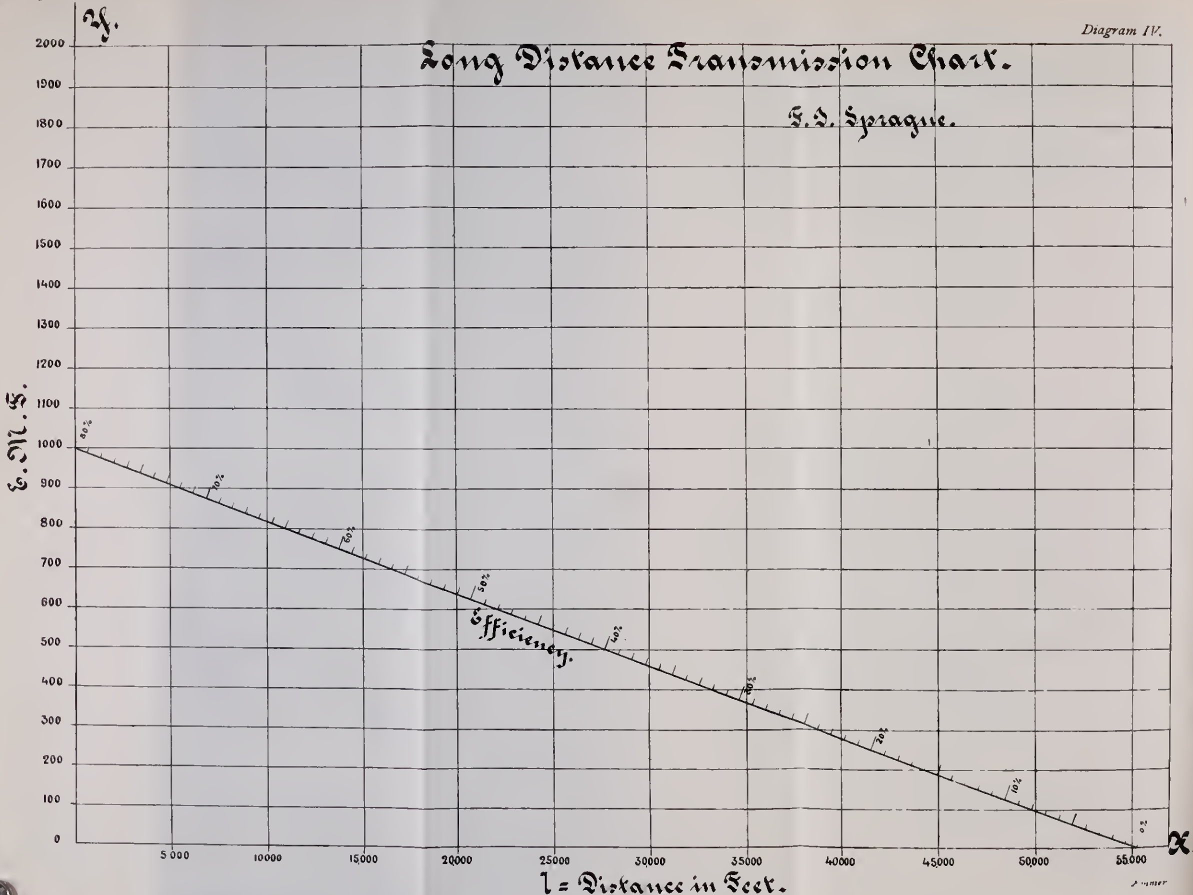
We can, as I will soon show, make a graphic representation of these facts, which will save much labor and will give at a glance the various limitations.

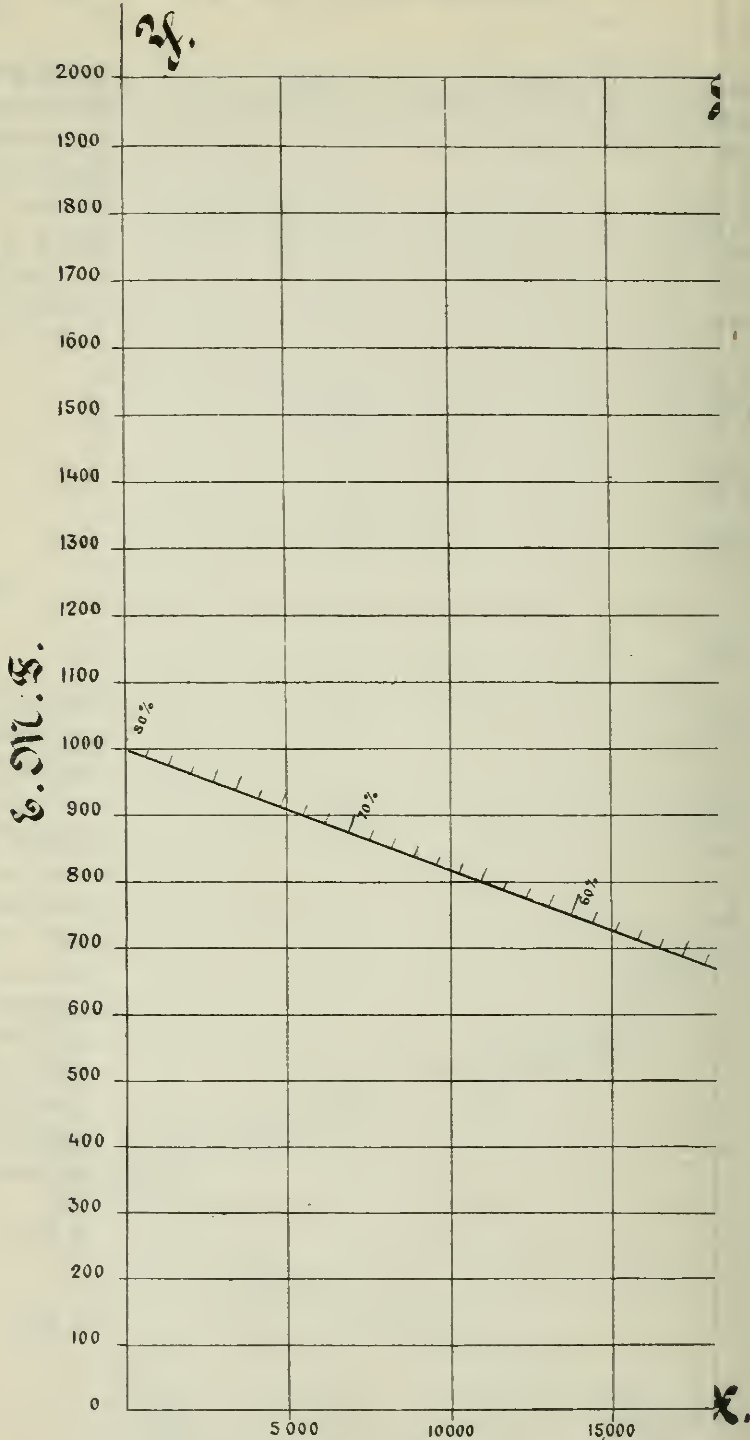
Referring to the general equation we can make, for various efficiencies, a table as follows:

$$\lambda = 50\ \% \qquad C = 2\,K + 2\,L + \tfrac{3}{4}\,(K + L) + M + \frac{P}{n}$$

$$55\ \text{“} \qquad \text{“} \qquad \tfrac{20}{11}\,K + \tfrac{20}{11}\,L + \tfrac{25}{44}\,(K + L) + M + \frac{P}{n}$$

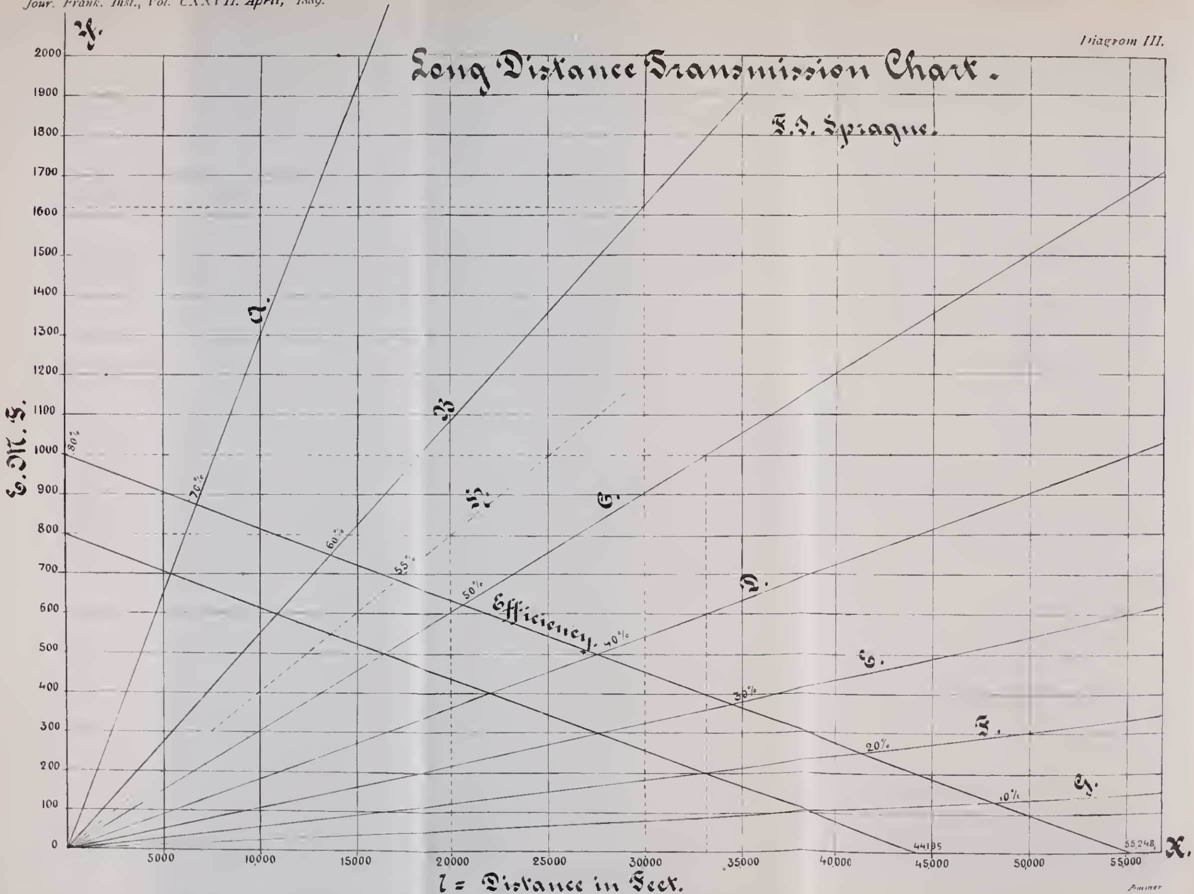
Diagram IV.

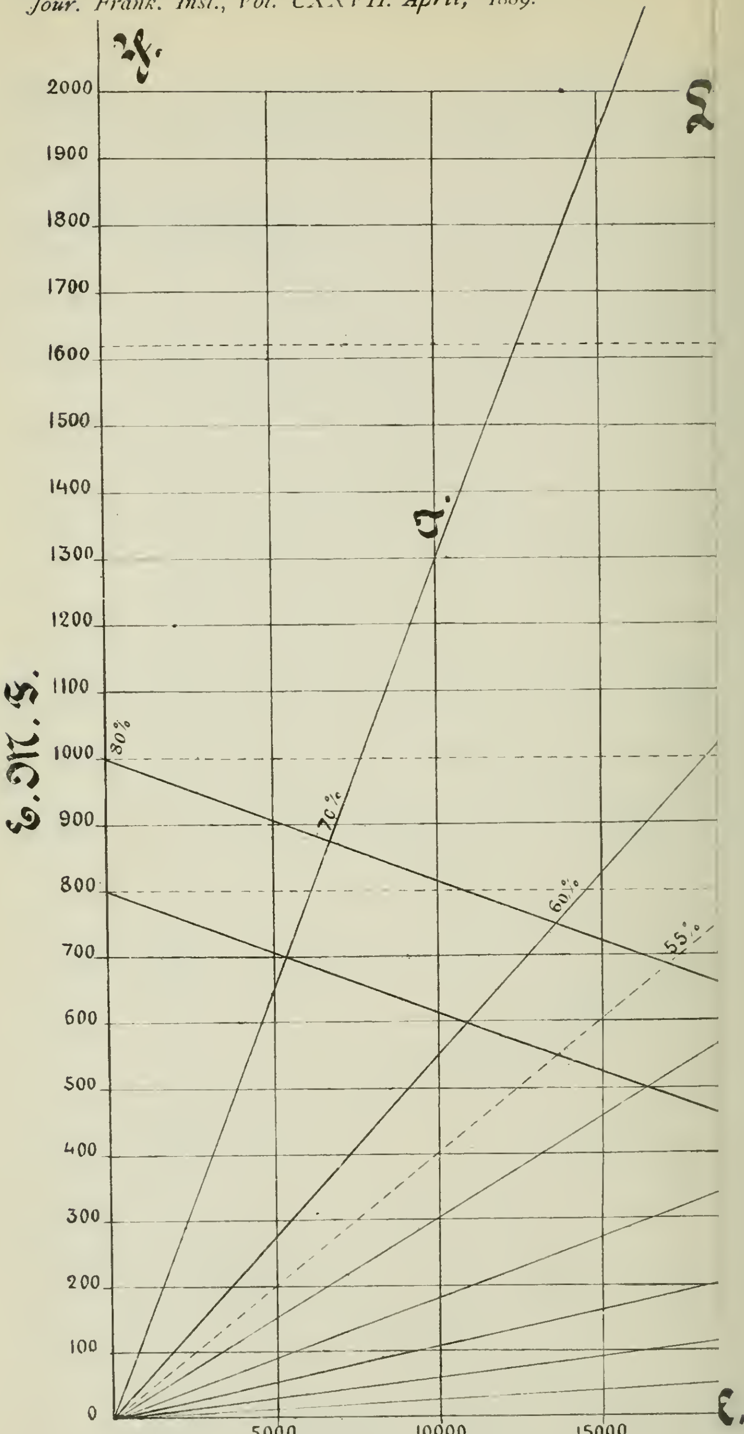

Long Distance Transmission Chart.
F. J. Sprague.
Y.
E. M. F.
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
80%
70%
60%
50%
40%
30%
20%
10%
0%
Efficiency.
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
X.
l = Distance in Feet.



Y.
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
E.M.F.
80%
70%
60%
5000
10000
15000
X.

Diagram III.


Long Distance Transmission Chart.
F. J. Sprague.
Y.
E. M. F.
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
A.
B.
B'.
C.
D.
E.
F.
G.
Efficiency.
80%
70%
60%
55%
50%
40%
30%
20%
10%
44195
55,248
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
X.
l = Distance in Feet.


V.
W.
E.M.F.
A.
C.
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
80%
70%
60%
55%
5000
10000
15000

$$60\,\% \quad C = \tfrac{5}{3}K + \tfrac{5}{3}L + \tfrac{5}{12}(K+L) + M + \frac{P}{n}$$

$$65 \text{ " } \quad \text{" } \quad \tfrac{20}{13}K + \tfrac{20}{13}L + \tfrac{15}{52}(K+L) + M + \frac{P}{n}$$

$$70 \text{ " } \quad \text{" } \quad \tfrac{10}{7}K + \tfrac{10}{7}L + \tfrac{5}{28}(K+L) + M + \frac{P}{n}$$

$$75 \text{ " } \quad \text{" } \quad \tfrac{4}{3}K + \tfrac{4}{3}L + \tfrac{1}{12}(K+L) + M + \frac{P}{n}$$

$$80 \text{ " } \quad \text{" } \quad \tfrac{5}{4}K + \tfrac{5}{4}L + \quad o \quad + M + \frac{P}{n}$$

and substituting the assumed values of K, L and M, we would have for the cost of transmission per horse-power delivered, exclusive of poles and line erection, and independently of the distance, the following table:

Efficiency, Per Cent.	*Water-Power.*	*Dynamo.*	*Wire.*	*Motor.*	*Electrical Total.*	*Water and Electrical.*
50	$40 00	$90 00	$48 75	$50 00	$188 75	$228 75
55	36 36	81 81	36 94	50 00	168 75	205 11
60	33 33	75 00	27 08	50 00	152 08	185 41
65	30 77	69 23	18 75	50 00	137 98	168 75
70	28 57	64 28	11 61	50 00	125 89	154 46
75	26 67	60 00	5 42	50 00	115 42	142 09
80	24 00	56 25	. . .	50 00	106 25	130 25

The graphic representation of the facts which have been set forth, and the construction of an electrical reference table, which will at once show the necessary elements, is a simple matter.

We have the equation.

$$E = \frac{\cdot 0905\,\lambda}{4 - 5\,\lambda}\,l$$

Let us lay off on the axis of x the distance in feet and on the axis of y the E. M. F. at the motor terminals.

Then for any value of λ the ratio of

$$\frac{E}{l}$$

is fixed, whatever the actual value, and we can draw the efficiency lines $O\ A$, $O\ B$, etc., for

$$\lambda = 70\%,\ 60\%, \text{ etc.,}$$

which will, with the different values of l and E, give us any required information. This, however, is not yet in a convenient and general form, and we wish to get some general intersecting efficiency line. By an inspection of the diagram we see that if a general efficiency line can be drawn, it must intersect the specific efficiency lines at such an angle that the intersected portions must be proportional to the differences of efficiencies. In other words, we must have the ratio

$$\frac{E}{\lambda}$$

for any particular value of E constant. Referring to the above equation and transposing we have,

$$\frac{E}{\lambda} = \frac{5\ E + \cdot 0905\ l}{4} \tag{25}$$

It is evident that if we are to get this equation to give a straight line, we must make the condition

$$\frac{E}{\lambda}$$

a constant, r. Substituting we have—

$$\frac{E}{\lambda} = r$$

and

$$r = \frac{5\ E + \cdot 0905\ l}{4}$$

which will give in a series of parallel straight lines for various values of r and E corresponding.

Let $$r = 1000.$$

Then we have—

$$E = 1000\ \lambda$$

and

$$E = \frac{4\ r - \cdot 0905\ l}{5}$$

When

$$E \text{ and } \lambda = 0,\ 4\ r = \cdot 0905\ l$$

or

$$l = 44199,$$

and when $l = 0$,

$E = 800$

and $\lambda = 80\%$.

Plotting this, we have a general efficiency line. Assuming another value for r, we get another straight line parallel to this, but one line is sufficient. It is, however, of prime importance. On it we lay off the efficiency percentages in equal increments, from 0 to 80%, and the chart which needs consist only of the axes of x and y, on which the E. M. F. and distance are laid off, and the efficiency intersecting line is ready for constant reference, and will give at a glance the graphic solution of all the ordinary elements of a transmission under the condition of least prime cost, and with the known efficiency of motors and dynamos. For example, suppose we wish to transmit a distance of 30,000 feet at a commercial efficiency of sixty per cent., what would be the required E. M. F. at the motor terminals? Drawing the efficiency line $O\ B$ till it meets the ordinate erected at $l = 30{,}000$, we find the E. M. F. to be 1,620 volts. On the other hand, suppose we are limited to 1,000 volts at the motor, and must have an efficiency of fifty per cent., what would be the limiting distance? Reversing the above process, we find it to be 33,500 feet. Suppose, again, that we must operate at a distance of 20,000 feet, and are likewise limited to an E. M. F. of 800 volts at the motor, what would be the required efficiency? Through the intersection of the co-ordinates of electro-motive force and distance, we draw the efficiency line $O\ H$, and at its intersection find the efficiency to be about fifty-five and one-half per cent. Such, then, is this method of graphic determination.

Commercial practice, however, may make it inadvisable to meet every phase of a transmission just as the theory may demand, and since in manufacture it may be advisable to build motors for three standard potentials, say, for 400, 800 and 1,200 volts, allowing the dynamo to be driven at the E. M. F. demanded by theory, we may be required to make a table something like the following. It will be noted that the prices here differ somewhat from those given in the preceding examples, and are illustrative rather than perfectly accurate.

Distance in Feet.	E. M. F. at Terminals of Motor.	Commercial Efficiency.	Per Horse-power Delivered by Motor.											Remarks.
			Horse-power required at Dynamo.	Weights in Pounds.					Cost in Dollars and Cents.					
				Dynamo.		Motor.		Wire, uncovered.	Water-power.	Dynamos, etc.	Uncovered Wire, etc.	Motor, etc.	Total for Electrical Equipment.	
				Net.	Gross.	Net.	Gross.							
5,000	400	65	1·53	153	168	97	130	68·88	30·60	61·20	17·22	45·00	123·42	Copper, ... @ $0.25
10,000	"	54	1·85	185	204	"	"	144·32	37·00	74·00	36·08	"	155·08	Dynamos, ... @ $40.00
15,000	"	47	2·13	213	234	"	"	210·88	42·60	85·20	52·72	"	182·92	Motors, ... @ $0.45
5,000	800	71	1·41	141	155	"	"	39·68	28·20	59·93	9·92	47·50	117·35	. . . .
10,000	"	65	1·53	153	168	"	"	71·72	30·60	65·03	17·93	"	130·46	Copper, ... @ $ 0.25
15,000	"	59	1·69	169	186	"	"	110·92	33·80	71·83	27·73	"	147·06	. . . .
20,000	"	54	1·85	185	204	"	"	150·32	37·00	78·63	37·58	"	163·71	Dynamos, ... @ $42.50
25,000	"	50	2·00	200	220	"	"	187·52	40·00	85·00	46·88	"	179·38	. . . .
30,000	"	47	2·13	213	234	"	"	219·68	42·60	90·53	54·92	"	192·95	Motors, ... @ $47.50
35,000	"	45	2·22	222	244	"	"	242·80	44·40	94·35	60·70	"	202·55	. . . .
10,000	1,200	69	1·45	145	160	"	"	51·84	29·00	65·25	12·96	50·00	128·21	. . . .
15,000	"	65	1·53	153	168	"	"	74·60	30·60	68·85	18·65	"	137·50	Copper, ... @ $0.25
20,000	"	61	1·64	164	180	"	"	101·28	32·80	73·80	25·32	"	149·12	. . . .
25,000	"	57	1·75	175	193	"	"	130·80	35·00	78·75	32·70	"	161·45	Dynamos, ... @ $45.00
30,000	"	54	1·85	185	204	"	"	156·32	37·00	83·25	39·08	"	172·33	. . . .
35,000	"	51	1·96	196	216	"	"	184·72	39·20	88·20	46·18	"	184·32	Motors, ... @ $50.00
40,000	"	49	2·04	204	224	"	"	205·52	40·80	91·80	51·38	"	193·18	. . . .
45,000	"	47	2·13	213	234	"	"	288·44	42·60	95·85	57·11	"	202·96	. . . .
50,000	"	45	2·22	222	244	"	"	252·52	44·40	99·90	63·13	"	213·03	. . . .

NEW FORMS OF VENTURI TUBES.

[From the Annals of the Laboratories of the Department of Civil Engineering of Cornell University. Section of Hydraulic Research. Preliminary Investigation by Prof. I. P. Church, Superintendent of the Hydraulic Laboratory.]

Having recently designed and made a few experiments with the two forms of short pipes or tubes to be described below (and there called B and C), for the discharge of water from the side of a large vessel, the writer finds his expectations so far realized as to venture to speak of them as "new forms of Venturi tubes."

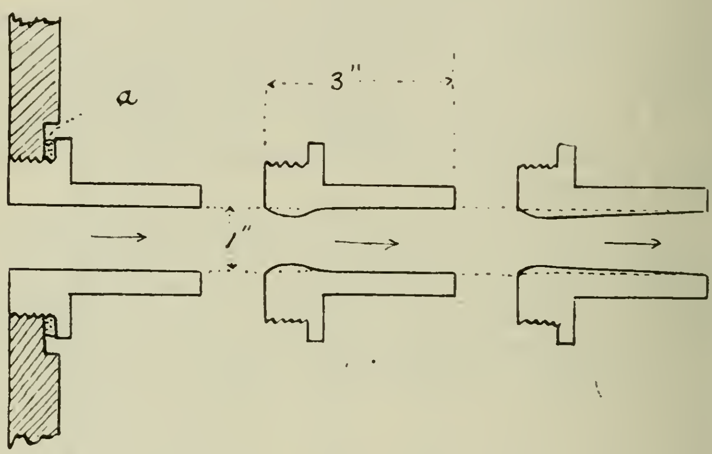
In all records, accessible to him, of experiments on the discharge of water through short pipes having conically divergent interior walls, stress has always been laid on the circumstance, so surprising to the novice, that a greater rate of discharge takes place than would occur through an orifice in thin plate, or through a short cylindrical pipe, having an area of discharge equal to the sectional area at the *narrowest* part of the Venturi tube. Again, in Mr. Francis' experiments (Lowell Hydraulic Experiments) the discharge was made under water, to ensure the filling of the tubes; and in none of his experiments was a higher co-efficient of efflux attained than 0·782; understanding by the co-efficient of efflux the abstract number μ in the following formula (to be used in this paper):

$$\mu = \frac{Q}{F\sqrt{2gh}} \qquad (1)$$

where Q is the volume of water discharged in a unit of time; h the "head" (or vertical distance of the centre of the discharging orifice from the surface of the still water in the supply tank when the discharge is into the air, or the difference of level between the surfaces of the head and tail waters when the discharge takes place under water); while

F is the internal sectional area of the discharging end of the tube, and g the acceleration of gravity.

The special feature of the pipes now to be described is that they enable a greater discharge to occur than through an ordinary cylindrical short pipe with an internal diameter equal to that of the *widest* part of the former; or, to express it in a form rather paradoxical to the uninitiated, a greater discharge may be obtained by *partially filling up*, in a special manner, the interior of a short pipe originally cylindrical, than with the same pipe before this encroachment



A B C

Fig. 1.

on the passage-way, under the same head. Another way of putting it would be to say that while the Venturi tube as previously constructed discharges more water than the *inscribed* cylindrical surface, those now under consideration discharge more than the *circumscribed* cylinder.

It is well known (see p. 467 of "Hydromechanics," *Encyc. Britan.*) that when a pipe conducting water includes a portion containing a smooth and gradual enlargement of sectional area (the change of size not being extreme, not more than 10 to 6, say, but little loss of head occurs on this account during steady flow with full sections, the loss of

kinetic energy being made good by a (nearly) equivalent gain of "pressure energy," provided that the discharging end of the pipe is at some distance away. It therefore seemed probable to the writer that a considerable portion of the loss of head (about one-third of the total head in such a case) occurring during flow through a short cylindrical pipe might be prevented, and the discharge correspondingly increased, by smoothly guiding the stream in its enlargement from the narrow part of the *vena contracta*, together with filling up with solid material the space around the contracted vein, otherwise occupied by eddying water.

The three tubes, *A*, *B* and *C*, of *Fig. 1*, which shows longitudinal sections through their axes of figure, all cross-sections being circular, were therefore constructed; being made of brass, and with smooth internal surfaces. In all three tubes the sections at entrance and also those at the discharging ends are circles of one inch diameter, while the length of each is three inches.

Tube *A* is an ordinary straight cylindrical tube.

In *B*, the internal surface follows the form of the *vena contracta*, as it would occur with an orifice in thin plate, until reaching a point 0·50 inch from the plane of entrance, at which point the diameter is 0·80 inch, following Weisbach's measurement of the contracted vein (see Coxe's *Weisbach*, page 822), while in the next half inch of length, by a smooth reversed curve, the longitudinal profile regains the original full diameter of one inch, the remaining two inches of the tube being cylindrical.

In *C*, as in *B*, the interior is made to fit the contracted vein for the first half inch of length, the remainder being conically divergent until at exit the diameter is one inch. The junction of the straight line and the curve is smoothly rounded in longitudinal profile.

The Hydraulic Laboratory of the Civil Engineering Department at Cornell is provided with a hydraulic "regulator" or "pressure chamber," consisting of a strong cylinder of cast iron, one foot in internal diameter, the ends being composed of two discs or plates, twenty inches apart (see *Fig. 2*). Each of these plates has a central aperture,

2·25 inches in diameter and furnished with a screw thread. Into the aperture at one end of the "regulator" is fitted a two-inch supply pipe, connecting with the reservoir main and provided with a valve gate, while that in the other plate serves as a nut, or socket, into which may be inserted any mouth-piece or pipe with which it is desired to experiment.

The axis of the "regulator" is horizontal and by proper management of the valve *V*, in the supply pipe, a pressure may be maintained in the chamber from one atmosphere

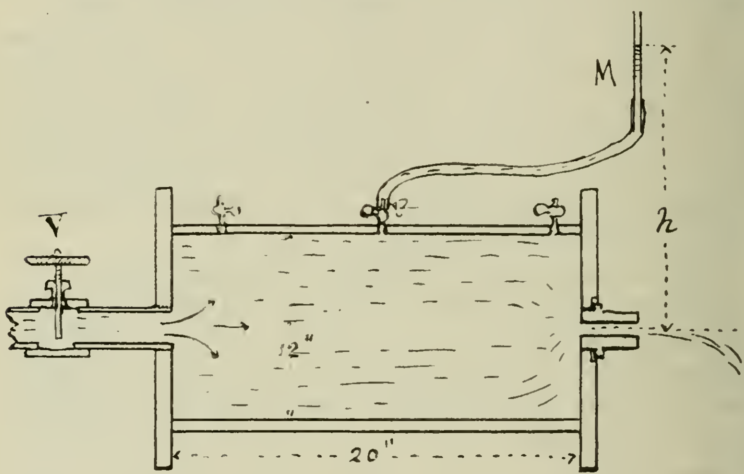


FIG. 2.

(absolute) up to the hydrostatic pressure due to the reservoir-head of about eighty feet, according to the rate of flow permitted to take place and the size of the attached mouth-piece or other fitting. This internal pressure can be measured by a mercury manometer of the U-form, over nine feet in height, one branch of the tube being open to the air; or, when small, by the height of a water column *M*, in a glass tube; connections of rubber tubing being made to pet-cocks inserted in the upper side of the "regulator." The internal section of the chamber being very large, compared with that of any pipe or mouth-piece used in connec-

tion with it, the water is in most experiments considered to have no appreciable "velocity of approach." In the experiments with the short pipes, above mentioned, the head was measured from the middle of the pipe section to the top of the water column in the glass tube connecting with one of the pet-cocks, the air originally in the apparatus having first been entirely displaced by water, and the pipe having been screwed into the socket no further than necessary to make the internal vertical plane of the former flush with that of the latter. A rubber washer of proper thickness prevented leakage. See *a*, *Fig. 1*.

The jet flowing from the pipe was received in one end of a conductor pipe, properly inclined, from the other extremity of which the stream could be allowed to run to waste in the drain, or, by a sudden shift, to empty into the measuring tank. The latter was of galvanized iron, twenty inches deep and two feet square horizontally, resting on the platform of a Fairbank's scale of 400 pounds capacity. The duration of flow was observed by a watch; with the chance of an error of no more than a quarter second, probably, in each experiment. Longer times of flow than those employed would have diminished the importance of this error, but a limit was set by the size of the measuring tank. For a similar reason the greatest head used was four feet.

Another source of slight inaccuracy lay in the fact that the pressure in the reservoir main was subject to frequent fluctuations, producing corresponding oscillations in the water column in the glass tube serving as manometer. In no experiment, however, was the range of oscillation more than three or four hundredths of a foot and in very few as much as that; the average position of the column being estimated. As already stated, the discharge took place into the air. The end of the tube was visibly filled in each experiment, and the temperature of the water was about 40° F. The weight of the water in the tank was observed at the beginning and end of each experiment, readings being taken to the nearest quarter pound. Assuming a cubic foot of water to weigh 62·5 pounds, the total volume discharged was computed in an obvious manner, as well as

the volume per minute. Referring to equation (1) as the basis of computation, we have in each case $F = 0{\cdot}005454$ square feet; and

$$\sqrt{2g} = 8{\cdot}02$$

(for the foot and second), according to the table given on p. 19 of Mr. Hamilton Smith's *Hydraulics*. Hence with Q expressed in cubic feet per minute, equation (1) becomes

$$\mu = \frac{Q \text{ (in cubic feet per minute)}}{60 \times {\cdot}005454 \times 8{\cdot}02 \sqrt{h \text{ (in feet)}}} \qquad (2)$$

The annexed table shows the results of the experiments, both as to observed and computed quantities. In the last column are given the averages for μ in the case of each pipe under two feet head (approximately) and, also, under four feet head, to show the influence of a change of head. The increased discharge given by tube C over that of A is very marked; while the performance of B, notwithstanding the fact that its enlargement of section is much more abrupt than with C, is only slightly behind that of the latter, which seems to show that the filling-up around the *vena contracta*, a feature common to both B and C, is the most essential condition of their superiority to A.

With the increased facilities of a new laboratory in the special building now in process of construction, it is hoped to repeat these experiments under more favorable conditions, and to employ a much greater range of heads, as well as a variety of sizes of pipe.

Tube employed.	Number of Experiment.	Observed Quantities.				Computed Quantities.				
		Head in Feet (h).	Duration in Seconds.	Initial Weight. Pounds.	Final Weight. Pounds.	Total Weight. Pounds.	Total Volume. Cubic Feet.	Volume per Minute, Cubic Feet (Q).	Co-efficient of Efflux μ.	Averages for μ.
A	1	2·0	60	100·5	287·0	186·5	2·984	2·984	·804	·814
	2	2·0	60	82·0	271·0	189·0	3·024	3·024	·815	
	3	2·0	60	98·0	289·0	191·0	3·056	3·056	·823	
	4	2·02	60	119·5	309·0	189·5	3·032	3·032	·813	
	5	4·03	45	64·5	267·5	203·0	3·248	4·331	·822	·821
	6	4·02	45	76·0	278·0	202·0	3·232	4·309	·819	
	7	4·02	45	84·75	287·75	203·0	3·248	4·331	·823	
B	8	2·02	60	110·0	314·0	204·0	3·264	3·264	·875	·882
	9	2·0	60	112·5	316·5	204·0	3·264	3·264	·880	
	10	2·0	45	103·5	257·5	154·0	2·464	3·285	·885	
	11	2·0	60	85·0	290·5	205·5	3·288	3·288	·886	
	12	1·99	60	89·5	294·5	205·0	3·280	3·280	·886	
	13	3·96	45	74·75	293·0	218·25	3·492	4·656	·891	·892
	14	3·97	45	100·5	320·0	219·5	3·512	4·683	·896	
	15	3·97	45	101·5	317·5	216·0	3·456	4·608	·881	
	16	3·97	45	101·5	322·5	221·0	3·536	4·715	·902	
C	17	1·98	60	53·0	265·0	212·0	3·392	3·392	·919	·901
	18	1·98	60	84·0	291·5	207·5	3·320	3·320	·899	
	19	2·0	60	103·5	312·0	208·5	3·336	3·336	·899	
	20	2·0	60	103·5	310·0	206·5	3·304	3·304	·890	
	21	2·01	60	70·5	279·0	208·5	3·336	3·336	·897	
	22	4·0	30	97·0	245·0	148·0	2·368	4·736	·902	·914
	23	4·06	45	65·5	293·5	228·0	3·648	4·864	·920	
	24	4·04	45	68·5	294·0	225·5	3·608	4·811	·912	
	25	4·05	45	59·5	288·0	228·5	3·656	4·875	·923	

Ithaca, January 15, 1889.

DIFFERENTIAL METHOD OF COMPUTING APPARENT PLACES OF STARS FOR LATITUDE WORK.

BY ERASMUS D. PRESTON, Coast Survey Office, Washington, D. C.

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When a number of stations have been occupied during a season for the determination of latitude, the necessary reductions of the stars from mean to apparent positions requires considerable time. With a view of accomplishing the task sooner, as well as making the work much less laborious, and at the same time having an accuracy fully equal to the requirements of the case, the following investigation was made. Although the superiority of this method is most marked when the observations only extend over three or four days, and when several stations with long star lists are to be reduced at one time, yet in any case it is considerably shorter than the usual logarithmic method. Little is gained by observing a star more than three times; and with the improved mean star places now available and allowing a probable error of observation of 0″·50 for an experienced observer, with good weather, three evenings work will reduce the uncertainty of the latitude to about ten feet. So that this method may be employed nearly always with great advantage.

The usual computation of the apparent places of stars for the dates of observation may be abridged in two ways: first, in using Crelle's tables instead of making the ordinary four-place logarithmic computation; and, second, after having one date getting a neighboring date by the application of differential quantities derived from the usual formulæ.

If we consider the tabular differences of the quantities that vary with the date as the differential coëfficients of the

quantities with respect to the time at the date already computed, we have the following formulæ as representing the change in declination between the two dates:

$$- g\ d\ G \sin (G + a) + dg \cos (G + a)$$

$$[- h\ d\ H \sin (H + a) + dh \cos (H + a)] \sin \delta$$

$$di \cos \delta$$

The following relations exist between the independent star numbers:

$$G = \tan^{-1} \frac{B}{K\,A} \qquad H = \tan^{-1} \frac{C}{D}$$

$$g = \frac{B}{\sin G} \qquad h = \frac{C}{\sin H} \qquad i = C \tan \omega$$

Where the letters have the signification given in the American ephemeris, K is the precession constant $20''\cdot0533$.

The greatest departure from a uniform change for a five-day period in B and A, is due to terms depending on the moon's longitude. The terms depending on the longitude of the sun, of the moon's ascending node, and on the longitude of the sun's and moon's perigees, being either quite regular for a five-day period, or else being extremely small. In 1887, G does not change as much as $3°$; g changes less than $0''\cdot5$.

The tangent of H varies inversely as the tangent of the sun's mean longitude. Hence H varies nearly uniformly throughout the year, changing about $1°$ daily. h depends on the same quantity and has its maximum values at the solstices and its minimum ones at the equinoxes. For a five-day period it departs little from a uniform change. i varies also with the sun's longitude and has its maximum with the minimum h and *vice versa.* The greatest daily change in i is not much more than $0''\cdot10$, while that of h is very much less.

The value of G is in general principally affected by changes in terms depending on the sun's and moon's longi-

tude, and on the longitude of the moon's ascending node. The latter has a daily motion of $3'$. The first two have a daily motion of about 1° and 13°, respectively. $\tan G$ varies directly as B and inversely as A, and since the former depends on the cosines and the latter on the sines of the above functions, they do not both change rapidly at the same time. At 90° $\cos \Omega$ changes 0·005 in five days and the change in $\cos 2\ \Omega$ may be neglected. When $\odot = 45^\circ$, $\cos 2 \odot$ has a change of 0·087. For an equal period and position $\cos 2$ ☽ changes about one unit. The terms in which these quantities enter will therefore vary by $0''\cdot05$, $0''\cdot05$ and $0''\cdot09$, respectively. Hence the greatest change in B comes from the change in the moon's longitude. In case of all these changes having their maximum at the same time, and tending in the same direction, the value of B would only be changed by about $\frac{1}{50}$th the part of itself, and since

$$d \tan^{-1} y = \frac{d y}{1 + y^2}$$

the change in G dependent on B will not be more than about 1°.

The longitude of the moon's ascending node does not pass through 90° until 1890, but its change is slow compared with that of the others, and in its relation to B we need not for the present consider its effect on G.

The above quantities enter A as a sine function with coëfficients about $\frac{1}{20}$th of those for B, but the precession factor appearing in the denominator of $\tan G$ makes the changes in numerator and denominator about equal for maximum values of the function. But G being determined by its tangent, the magnitude of its changes depends also on the absolute values of B and A—for when B is small a given change in A has very much more influence on the angle. In general, we may expect changes in G of less than a degree per day.

When we have very small values for B, as in 1890, and also very small values for A, as in May, a combination of these may give a change in G for five days, amounting to

30° or more; but, as will be shown later, this does not render the method inapplicable.

When B has its largest value, G does not change more than, say, 5°, which reduces the product of dg by $d\,G$ to a quantity less than $0''\cdot10$, and when $d\,G$ is very large dg is small enough to reduce the product considerably under $0''\cdot10$, so that, in general, we may estimate the neglected term to be less than $0''\cdot10$. The product of any two of these differences that actually occur together is usually only a few hundredths of a second, so that the method will satisfy all the requirements of latitude work.

These considerations show that the stars' position may be derived, with all necessary accuracy, by the application of differential quantities, when the difference between the two dates is not more than five days. The following two forms show the reduction by both methods. It will be noticed that the method by differences involves only about half the number of figures used in the logarithmic method, besides requiring very little mental labor.

Star 289.—Method by Logarithms.

	h. m. s	α ° ′	*sin δ*	*cos δ*
α_1	3 11 40	47 55	9·7453	9·9196
δ_0		33 48		
	$\delta' - \delta$	$g \cos (G + \alpha)$	$h \cos (H + \alpha)$	$i \cos \delta$
		° ′	° ′	
	January 20th.	151 5	19 9	0·5408
	"	9·9422	9·9753	− 3·4
		0·8751	1·0219	
	− 0·45	− 7·50	10·52	
	January 25th.	148 59	14 15	0·5995
	"	9·9330	9·9864	− 3·98
		0·8499	1·0301	
	− 0·34	− 7·08	10·72	
		January 20th. ° ′	*January 25th.* ° ′	
	G	103 10	101 4	
	H	331 14	326 20	
	log g	0·9329	0·9169	
	log h	1·3013	1·2984	
	log i	$0·6212_n$	$0·6799_n$	

STAR 289.—METHOD BY DIFFERENCES.

	h. m. s.	a ° ′		
a_0 =	3 11 40	47 55		
δ_0 =		33 48		
		$(G + a)$	$(H + a)$	
		° ′	° ′	
	January 20th.	151 5	19 9	*January 25th.*
	$\sin (G + a)$	+ ·483		+ ·15
	$\cos (G + a)$	− ·875	− 7·50	+ ·27
	$\sin (H + a)$	+ ·328		+ ·56
	$\cos (H + a)$	+ ·945	10·51	− ·12
	$\sin \delta$	+ ·556		+ ·24
	$\cos \delta$	+ ·831	− 3·47	− ·51
			− 0·46	+ ·15
		January 20th. ° ′		
	$G =$	103 10	$d\,G =$	− ·0367
	$H =$	331 14	$d\,H =$	− ·0855
	$g =$	+ 8·57	$d\,g =$	− ·31
	$h =$	+ 20·01	$d\,h =$	− ·13
	$i =$	− 4·18	$d\,i =$	− ·61
			$-g\,d\,G =$	+ ·314
			$-h\,d\,H =$	+ 1·71

EXPLANATION OF COMPUTATION.

In both methods the quantities below the double line are the same for all stars, varying only with the date, and are therefore written but once for each station. The first computation is the usual logarithmic one, and needs no explanation. The second is by Crelle's tables and differences. In the first column are the natural trigonometric functions. In the second are the quantities $g \cos (G + a)$, $h \cos (H + a) \sin \delta$ and $i \cos \delta$, the sum of which is the reduction to apparent place for January 20th. The proper motion of the star is not considered in comparing the two methods. The third column contains the products of the constant multipliers by the corresponding sines and cosines to obtain the following quantities of the differential equations:

$$- g\ d\ G\ \sin\ (G + a) + dg\ \cos\ (G + a)$$

$$[- h\ d\ H \sin\ (H + a) + dh\ \cos\ (H + a)]\ \sin\ \delta$$

$$di\ \cos\ \delta$$

It should be stated that $d\ G$ and $d\ H$ are first reduced to linear quantities. The sum of this last column omitting

the two middle values, gives the quantity to be applied to the reduction for January 20th to obtain that for January 25th, and will in most cases be found to be correct within one or two hundredths of a second.

The method by differences is considered to be a saving of about one-half the usual time, besides being very much easier, as many as thirty pairs being computed for two dates, in about seven hours, by a person familiar with the method. After the computation of the first date, the corrections to be applied to these to get those for the second date were found in two hours. But in order to work advantageously each step is taken up systematically and carried through the entire number of pairs, and often two steps may be carried along simultaneously where the multipliers are single or when the tables may be kept open two places at once. Care should be exercised to avoid using more places than are necessary. For example, in the direct computation for the first date, three figures are sufficient, except where h enters. It is not considered essential to secure exactly the fourth place here, but it may be done with Crelle's tables mentally, and with very little labor, by taking the nearest unit in the third place and applying to the product the algebraic sum of the unit's place by the thousandths, one or two places at most only being considered. In forming the products for the differences two places generally need only be retained.

The difference of $0''\cdot03$ between that calculated rigorously for January 25th and that derived by the formulæ is due to the fact that the differences have been treated as differentials and not as finite differences. The neglected product, dh, $d\,H$, $sin\,(H + \alpha)$, does not amount to more than $0''\cdot003$ and need not be regarded when $sin\,\delta$ is as much as $0\cdot90$, for, as a rule, stars are not observed above $65°$ declination.

If we had treated the difference in the cosine of $(H + \alpha)$ as a finite difference, using the formula,

$$-\,2\,sin\,(\gamma + \tfrac{1}{2}\,\Delta\gamma)\,sin\,\tfrac{1}{2}\,\Delta\gamma$$

instead of $-\,sin\,\gamma\,d\,\gamma$, the agreement would, of course, have

been perfect; the essential points in the method being that the differences are considered as differentials, and the term involving the product of the differences is neglected.

It might be supposed that if we have a difference of $0''.03$ in the position of a star for a difference in H of, say, $5°$, that this discrepancy would amount to a quantity entirely inadmissible in the case of G, in May, 1890, where the difference is upwards of $30°$; but, since, when these excessive changes in G occur, B is necessarily quite small, because the longitude of the moon's ascending node is near $90°$, the discrepancy between the values of $g \cos (G + a)$, calculated by the differential formulæ, and those by actual multiplication, does not much exceed that in the present case; in fact, they only differ by $0''.05$. Indeed, the large discrepancy in the present case is due to the fact that the error committed in neglecting the formula for finite differences must be multiplied by h, which increases it twenty-fold. g in the extreme case of 1890 is $0''.8$, hence only $\frac{1}{25}$th of h for this case. But the discrepancy for the values of May, 1890, comes from another source, viz: From the product of the two differentials dg and $d\,G$, and even then will only occur for a few pairs where $(G + a)$ is near $90°$, and where the sine is large. It will be noticed that, assuming a value for $(G + a)$, which gives the most rapid change in the cosine, also gives a large value for the sine, and hence increases the value of the term $dg \sin (G + a)\, d\,G$, there is a combination of circumstances tending to increase the discrepancy to $0''.08$. This must be regarded, therefore, as a very exceptional case. When we consider that the probable errors of the declinations of the individual stars are several times as large, this may be neglected.

In general, the errors introduced by this method are quite insignificant, even admitting the declinations to be absolutely true, for errors of observation will much exceed these. Besides, for the extreme case of 1890, we have assumed a value for $(G + a)$, which would give the greatest possible change in the cosine for the change in G under consideration; that is, a value extending from about $85°$ to $105°$. Moreover, since this term depends on the star's right

ascension, for any station this extreme case would only apply to a few pairs which involved values of $(G + a)$ passing through the points 90° or 270°; no night's work ever lasting long enough to pass through or even near them both.

When the observations do not extend beyond five days, the last date is derived from the first by differences. For work extending over a period from five to fifteen days, the middle date is actually computed, and the first and last obtained by differences. Where on account of bad weather observations are very much scattered, it is better to make separate computations for each date. Under ordinary circumstances, three successive nights are all that are required, which involves differences in the star numbers for only two days. In this case, the result by differences will be found to be identical with that of a rigorous calculation. For where $d\ G$ and $d\ H$ are about 2°, and $d\ g$ and $d\ h$ one or two-tenths, their product does not affect the hundredths place; and the change in the cosine of an arc, whether computed as a differential or a finite difference, is practically the same for differences of arc of 2°, the discrepancy never amounting to a unit in the hundredths place.

Assuming the probable error of observation to be 0″·50, which is about the usual experience, and the probable error of one declination to be 0″·30, we find the following relations between the number of nights, number of pairs, and the probable error of the mean result.

No. of Nights.	Number of Pairs.					
	5	10	15	20	25	30
	Resulting Probable Error of Mean Result.					
	″	″	″	″	″	″
3	0·17	0·12	0·09	0·08	0·07	0·07
5	·15	·10	·08	·07	·06	·06
7	·13	·09	·07	·06	·06	·05

SPACING THE ELLIPSE.

By George B. Grant, Lexington, Mass.

I have frequently found it necessary in the course of my business, which is specially confined to the making and cutting of gear wheels, to cut the teeth of an elliptic gear. Although I have always used the greatest care and have had the advantage of experience and the best of tools, I have seldom succeeded in actually cutting such a gear to the combined satisfaction of myself and my customer, while, from a business point of view, nothing but a price that is almost prohibitory will make an order for such a gear in any way desirable.

The difficulty has been in the spacing of the curve so that the teeth could be evenly placed and give a smooth action. The usual method is to draw the curve and space it with the dividers, step by step, and, although the process is simple enough to describe, it is exceedingly clumsy, tedious, and inaccurate in operation.

Realizing that the only impediment to the general use of the elliptic gear for quick return motions and for other variations of speed, in positions where its simplicity and its positive action makes it unrivalled by any other mechanical movement, was the present expense of producing it and the poverty of the usual result, I undertook the construction of a special machine for the purpose. I had no difficulty in designing a machine that would keep the cutter accurately in the elliptic path, but it was only after a long search and many experiments that I found a device for spacing the elliptic outline that would serve that purpose even approximately.

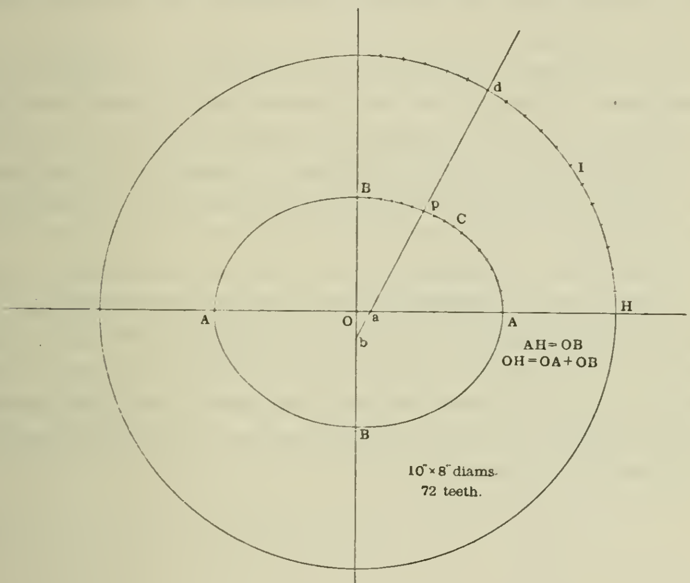
The result of my search was the device here described, and it can be easily applied with a degree of accuracy that is far beyond the requirements of actual practice.

In the figure, suppose the ellipse to be described on the principle of the common trammel, the two pins *a* and *b*

being confined to the two lines OA and OB, while the point p draws the curve.

Draw an index circle, I, from the centre, O, of the ellipse, and let its radius, OH, be equal to the sum of the radii, OA and OB, of the ellipse. Then, if the line, $b\ a\ p$, extended, accurately spaces the index circle at d, it will also space the ellipse with an accuracy that is practically perfect for cases that are in use for elliptic gears.

To show the accuracy of the device take a very common example. Given, an ellipse with a major diameter of ten



inches and a minor diameter of nine inches, with seventy-two teeth. This ellipse, used as a quick return motion, would give a ratio of slow stroke to quick return stroke of more than three to one, and when used for variation of speed, would give a variation of fastest speed to slowest speed of about six and one-half to one. It is, therefore, a practical example, elliptic gears being generally much more nearly circular.

For this example the errors in spacing, although theoretically present, are practically nothing. The chord of the

tooth space at the major apex A is ·41433 inch, while that at the minor apex B is ·41441 inch, giving an error of about one twelve-thousandth of an inch. The greatest error is on the quarter, at C, and not at the apices, but the difference between the greatest and the least tooth spaces is not over one two-thousandth of an inch.

If we take an extreme case we shall find a greater error. For diameters of twelve and six inches and seventy-two teeth, which would be wholly useless for practical purposes, the greatest error is still very small, not over one-seventieth of an inch, while the error between the apices is still practically nothing.

For the case shown in the figure, an ellipse having diameters of eight and ten inches and seventy-two teeth, the maximum error is one four-hundredth of an inch. This gear will give a ratio of greatest to least speed of sixteen to one, while as a quick return motion the ratio is more than five to one.

With the machine now being made I confidently expect to be able to cut elliptic gears quite as accurately as I can now cut circular gears, and at an expense that is but little greater. When the elliptic gear can be well and cheaply made, I see no reason why its use should not be increased ten-fold, for it is one of the neatest and most useful of mechanical devices.

AN INVESTIGATION OF SOME EXPERIMENTS ON A CENTRIFUGAL BLOWER DELIVERING AIR INTO THE ATMOSPHERE AT LARGE.

BY CHIEF ENGINEER ISHERWOOD, U. S. NAVY.

In the month of July, 1888, Passed Assistant Engineer James J. Barry, of the Corps of United States Naval Engineers, made an extensive set of experiments on a Sturtevant centrifugal blower delivering air into the atmosphere at large. The blower was situated in the machine shop of the New York Navy Yard, and was driven by an independent oscillating non-condensing engine articulated directly to it. It received its air from the still atmosphere of a very large room, and delivered its air into the same.

The writer has taken from Passed Assistant Engineer Barry's experiments, the three quantities that the latter directly determined for each experimental speed of blower, namely, the pressure of the air delivered, the velocity of the air delivered, and the number of revolutions made by the blower per minute, and has deduced from them the results which will be found in the following pages, adding also the necessary dimensions and descriptions of the blower and apparatus, in order that the reader may clearly comprehend the conditions and limitations of the trials.

The experiments were made with the blower driven at velocities varying from 1,250 to 1,950 revolutions per minute. They serve within their limits to determine the velocity in feet per minute with which, at different rotary speeds of the blower, the air was discharged into the atmosphere. Also, the volume and weight of air delivered into the atmosphere per revolution of the blower, and whether that volume and weight were affected by the rotary speed of the blower, and if so, in what degree. Also, to ascertain the pressures produced by the impacts of the discharged air at different velocities, as shown by the respective heights of the columns of water equilibrated by these impacts and measured between

the water surfaces in the two legs of a U-tube. Also, to determine the law connecting these heights of water columns with the velocities of air producing them. Also, to determine the relation between the velocity of the centre of the surface of the fans or blades of the blower and the corresponding velocity of air discharge. Finally, to determine the powers expended in producing the air compressions and discharges at different rotary speeds of the blower.

The oscillating steam cylinder driving the blower exhausted into the atmosphere, and its piston made one double stroke to each revolution of the blower. The indicated pressure on this piston could not be ascertained, owing to its great reciprocating speed. The diameter of the cylinder was $2\frac{1}{8}$ inches; the diameter of the piston rod on one side of the piston was $\frac{7}{16}$ inch in diameter, and on the other side $\frac{13}{32}$ inch in diameter; the stroke of the piston was $1\frac{1}{4}$ inches. The mean net area of the piston, exclusive of the cross areas of its piston rods, was 3·4065 square inches; and the space displacement of the piston per stroke, was 4·2581 cubic inches.

The centrifugal blower consisted of six radial flat fans or blades equispaced about their axis and revolving in a cast-iron case, with a side clearance of about $\frac{3}{32}$ of an inch wide. The outside diameter of the fans was $12\frac{1}{2}$ inches, and their inside diameter was seven inches. Each fan was connected to the shaft by an arm averaging $\frac{3}{4}$-inch in width. The radial depth of the fan was therefore

$$\left(\frac{12·5 - 7·0}{2} = \right) 2·75 \text{ inches.}$$

Each fan was a regular trapezoid; its breadth at its outer edge was $3\frac{3}{16}$ inches, and at its inner edge $3\frac{5}{8}$ inches, making its area

$$\left(\frac{3\frac{3}{16} + 3\frac{5}{8}}{2} \times 2·75 = \right) 9·3671875 \text{ square inches.}$$

The aggregate area of the six fans was 56·203125 square

inches. The circumference of the centre of surface of the fans was 2·5387 feet.

The vertical inside diameter of the case was 19·75 inches; the horizontal inside diameter of the case was $18\frac{1}{16}$ inches; the inside width of the case was $5\frac{1}{4}$ inches, with an inner reinforce or raised edge around the seven-inches diameter opening. The outlet for the air delivery was cylindrical, $6\frac{3}{16}$ inches in diameter, and 10 inches in length measured on its axis to the intersection of the same with the inside circumference of the case. The area of the air delivery was 30·069 square inches or 0·2088125 square foot.

The axis of the fans was not coincident with the axis of the case. The distance between the outer periphery of the fans and the inside of the case on the vertical diameter of the fans was 2·75 inches at top and 4·50 inches at bottom. The distance between the outer periphery of the fans and the inside of the case on the horizontal diameter of the fans was $2\frac{1}{16}$ inches at the air-delivery side of the case and $3\frac{1}{2}$ inches at the opposite side. The flat sides of the case were parallel and connected by a segmental curve of $3\frac{3}{32}$ inches radius. The cylindrical air discharge was horizontal and its bottom was tangent to the bottom of the case. In each flat side of the case was a circular opening of seven inches diameter, the one opposite the other; the centres of both were coincident with the axis of the fan shaft. These openings admitted air to both sides of the fan. The fan shaft was one inch in diameter and extended entirely through the case, the journals being held in pillow blocks outside the case. Where the fan shaft passed through the air-receiving openings of the case, it was sheathed by couplings of $1\frac{1}{2}$ inches outside diameter, deducting the cross area of which, and the area of a half-inch wide rib extending downwards from it, from the area of the seven-inches diameter air opening, there remains for the aggregate effective area of the two openings 70·685 square inches, or 2·35 times the area of the air delivery.

The side edges of the fans, on each side of the blower, were joined together by a ring of sheet iron of the radial depth of the fans, and the latter were riveted by their side

edges to these two rings, so that the air which had once entered between any two fans could not escape sideways, but had to be delivered at the outer periphery of the fans.

Nine sets of experiments were made with different rotary speeds of blower. The increase in the number of revolutions made per minute by the blower for each succeeding set of experiments, was by as nearly equal increments as possible. Each set consisted of twelve observations of each quantity, and the observations were taken at five minutes intervals, so that each set of experiments occupied one hour.

The velocity of the air in feet per minute leaving the blower, was obtained from a very sensitive helicoidal anemometer, well placed within the cylinder for the air-delivery and resting on the lower side of that cylinder, so that the axis of the anemometer was about midway between the axis of the cylinder and the side of the latter.

The number of revolutions made by the blower per minute, was obtained from a mechanical counter applied directly to the end of the fan-shaft.

The pressure corresponding to the impact of the air being discharged through the horizontal cylindrical air-delivery, was obtained by directly measuring the height between the water levels in the two vertical legs of an open ended glass U-tube, the ends of which were bent at right angles to the legs. One end of the tube was inserted horizontally well into the cylindrical air-delivery about midway between the axis and the circumference of the latter, while the other end remained horizontally in the atmosphere. The temperature of the atmosphere being 75° F., each inch high of water column was equivalent to a pressure of 0·036 pound per square inch.

The observations of the three quantities were made as nearly simultaneously as possible, the engine running at a uniform speed.

The pressure due to the impact of the discharged air varied, during the experiments, from 0·66 inch to 1·60 inches high of water column above the atmospheric pressure, equivalent to 0·02376 and 0·05760 pound per square inch.

A collation of all the experiments showed that this pressure was almost exactly in the ratio of the square of the velocity with which the air was discharged. The experimental pressures denoted by the U-tube were probably a little too small, due doubtless to the adhesion of the water to the sides of the U-tube. When the impact pressure is as small as in the case of these experiments, the pressure equilibrating the water adhesion to the sides of the tube may sensibly affect the absolute but not the relative results. The experimental determination of the increase of the impact pressure of the moving air, in the ratio of the square of the velocity of the air, is in conformity with the theoretical deduction; twice the mass of air in equal time moving with twice the velocity, being brought to rest in the U-tube, when the velocity of the discharged air is doubled, quadruples the resulting pressure.

The velocity in feet per minute of the discharged air, was in the direct ratio of the rotary speed of the blower, showing that the quantity of air delivered per revolution of the blower was the same at all rotary speeds of the blower within the experimental limits. The quotient of the division of the velocity of the discharged air in feet per minute, by the number of revolutions made by the blower in the same time, is a constant number.

As the rotary speed of the blower is in the direct ratio of the velocity of the air discharged from it, and as the impact pressure produced in the U-tube is in the ratio of the square of the velocity of this discharged air, the rotary speed of the blower is in the ratio of the square root of the corresponding impact pressure. Of course, the velocity of the discharged air is also in the ratio of the square root of the corresponding impact pressure.

A collation of all the experiments shows that the velocity of the discharged air, as measured by the anemometer, was 4,092 feet per minute, when the blower made 1,585 revolutions per minute, the impact pressure in the U-tube being at the same time equilibrated by a column of water one inch high at the temperature of 75° F., equivalent to a pressure of 0·036 pound per square inch. From these

quantities, the corresponding similar ones can be calculated according to the above proportions for any other speed of blower, velocity of discharged air, or pressure in the U-tube.

The impact pressure in the U-tube is exactly the pressure within the blower-case producing the velocity of the discharged air. Whatever pressure put this air in motion with any velocity whatever, that air will exactly reproduce when brought to a state of rest. This is a very important fact and shows that the air pressure within the case at the entrance of the horizontal cylinder discharging the air was exactly equal to the pressure denoted by the water column supported in the U-tube by the impact of the air.

The velocity with which the air should be discharged into the atmosphere under the pressure of 0·036 pound per square inch above the atmosphere, can be calculated as follows and compared with the experimental result. Assuming the air employed in these experiments to have been three-fourths saturated with aqueous vapor, to have had the temperature of 75° F., and to have been under the standard atmospheric pressure of 14·68757 pounds per square inch, it would weigh 0·07360785 pound per cubic foot, and there results for the velocity of such air into vacuo

$$\left(\sqrt{\frac{14\cdot68757 \times 144}{0\cdot07360785} \times 64\cdot346078} = \right) 1359\cdot7379 \text{ feet per second.}$$

The square root of the pressure 14·68757 pounds per square inch is 3·8324, and the square root of the pressure 0·036 pound per square inch above the atmosphere in the U-tube is 0·19, therefore the velocity of the discharging air should have been (3·8324 : 0·19 : : 1359·7379 :) 67·4121 feet per second. Experimentally the velocity was

$$\left(\frac{4092}{60} = \right) 68\cdot7000 \text{ feet per second,}$$

a remarkably close correspondence, proving the accuracy of the experiments, and the correctness of the assumptions on which the calculation was made.

The number of cubic feet of air delivered into the atmosphere by the blower per minute under the above conditions, allowing 0·82 for the coëfficient of discharge through the cylindrical air-delivery was

$$\left(\frac{30·069 \times 4092 \times 0·82}{144} = \right) 700·658,$$

or

$$\left(\frac{700·658}{1585} = \right) 0·44205552 \text{ cubic foot per revolution}$$

of the blower. These figures are equivalent to $(700·658 \times 0·07360785 =)$ 51·572529 pounds of air delivered by the blower per minute, or to

$$\left(\frac{51·572529}{1585} = \right) 0·032537873 \text{ pound}$$

delivered per revolution of the blower.

As each cubic foot of air of the above temperature and proportion of aqueous vapor contains 0·016862154725 pound of oxygen, the blower delivered $(700·658 \times 0·016862154725 =)$ 11·814603605 pounds of oxygen per minute, or 0·007454009 pound per revolution.

The circular velocity of the centre of surface of the fans of the blower, was $(2·5387 \times 1585 =)$ 4023·8395 feet per minute. It should have been the same as the velocity of the discharge; namely, 4,092 feet per minute, the difference being due to errors of observation and of instruments.

As the aggregate fan surface of 56·203125 square inches acted against the air pressure of 0·036 pound per square inch above the atmospheric pressure, the blower performed $(56·203125 \times 0·036 \times 4023·8395 =)$ 8141·484758344 foot-pounds of work on the air per minute, equivalent to 0·2467117 horse-power. In doing this work, however, the power expended by the engine in driving the blower may be considerably greater than the above, if the pressure of the inflowing air against the back of the fans were less than the quiescent atmospheric pressure, consequently the indicated horse-power developed by the engine cannot be deduced from the horse-power exerted by the fans in compressing the air against which they act. All that can be

inferred is that the above 0·2467117 horse-power exerted by the fans is a minimum to which about one-fifth must be added for the engine frictions, making the indicated horse-power not less than about 0·3, provided the atmospheric pressure followed with its full effect against the back of the fans.

The area for the delivery of the air was 30·069 square inches; the velocity with which the air was delivered was 4,092 feet per minute; and the pressure causing this velocity was 0·036 pound per square inch above the atmospheric pressure; hence, the work done upon the outgoing air was $(30{\cdot}069 \times 0{\cdot}036 \times 4092 =)$ 4429·524528 foot-pounds, or

$$\left(\frac{4429{\cdot}524528 \times 100}{8141{\cdot}484758344} =\right) 54{\cdot}4071 \text{ per centum}$$

of the work done by the fans upon the inflowing air. A considerable portion of the difference is doubtless due to regurgitation of the air compressed in the case, through the $\frac{3}{32}$-inch wide clearance space between the blower and the side of the case, equal in the aggregate to $(3{\cdot}1416 \times 7 \times 0{\cdot}1875 =)$ 4·12335 square inches. Also, to loss of *vis viva* by the air once put in motion by the fans, and then brought to rest in the case by opposing collisions, and requiring to be again put in motion before escaping.

If the quantity of air lost by regurgitation be taken to be in the direct proportion of the 4·12335 square inches of opening between the sides of the blower and the flat sides of its case, to the 30·069 square inches of opening for delivering the air, which assumption is warranted because the pressures producing the regurgitation, and the air-delivery are equal, then

$$\left(\frac{4{\cdot}12335 \times 100}{4{\cdot}12335 + 30{\cdot}069} =\right) 12{\cdot}0593 \text{ per centum}$$

of the air acted upon by the blower was thus lost by a mere mechanical, but inevitable imperfection of the blower fitting. Adding these 12·0593 per centum to the above 54·4071 per centum, there results 66·4664 per centum realized of the work done by the fans on the air, or, say, two-thirds, leaving one-third of the air acted upon by the fans, as the

fraction of that air brought to rest in the blower-case after having been put in motion by the fans. This one-third of the work done reappears as heat in the air, and is promptly lost by radiation. Two-thirds, then, are the true efficiency of the blower as a furnisher of air, philosophically considered, supposing the inflowing air to act with atmospheric pressure against the back of the fans. The practical efficiency, however, is only ($54·4071 \times 0·82 =$) 44·6138 per centum under the same conditions, the 0·82 being the coëfficient of reduction for the delivery of the delivering cylinder; and if the power applied to the blower-shaft by the steam cylinder be taken as unity, the practical coëfficient of the blower cannot exceed thirty per centum.

The continually changing air between the periphery of the blower and the case, may be considered to be compressed to the uniform pressure of 0·036 pound per square inch above the atmosphere by the centrifugal action of the fans, when the latter made 1,585 revolutions per minute.

The number of foot-pounds of work done by the outflowing air may be ascertained by using the data in another manner. The weight of air delivered per minute was 51·572529 pounds, and with the velocity of 4,092 feet per minute. The height through which a body must fall to obtain that velocity is 71·9443 feet. Now $71·9443 \times 51·572529 = 3710·349498$, which divided by the co-efficient of discharge 0·82 gives 4524·8164 as the number of foot-pounds of work done per minute by the outflowing air. This result is very nearly the same as the above 4429·5245 foot-pounds determined from the pressure and velocity of that air, and using of course, the entire air-delivery orifice.

The lacunes in the experimental data are the indicated power developed by the small steam cylinder driving the blower, the velocity of the air flowing into each side of the case, the pressure of the air within the case between the periphery of the blower and the circular side of the case, and the temperature of this compressed air. Nevertheless, so little is the experimental knowledge possessed on the subject of centrifugal air blowers, and so important is such knowledge when their extensive use in

the industrial arts is considered, that the experiments of Past Assistant Engineer Barry, made with the very limited means at his command, have great value.

The experiments in question, made with an apparatus of the kind and dimensions, and in the manner, and within the limits described, allow the following generalizations to be drawn.

(1) The quantity of the same air, volume and weight, delivered by the blower per revolution, is constant, let the number of revolutions made in a given time be what it may.

(2) The velocity of the air delivered, is in the direct ratio of the number of revolutions made by the blower in a given time.

(3) The velocity of the centre of the surface of the fans, is the same as the velocity with which the air is delivered.

(4) For any number of revolutions of the blower in a given time, the air pressure above the pressure of the atmosphere, reacting against the surface of the fans, and existing in the annular space between the periphery of the fans and the circular side of the blower-case, and causing the velocity with which the air is delivered, is equal.

(5) The velocity with which the air is delivered at the outer end of the delivering cylinder is the velocity due to the excess of the air pressure at the inner end of the delivering cylinder above the atmospheric pressure. This excess of pressure being known, the velocity can be calculated, and, *vice versa*, the velocity being known, this excess of pressure can be calculated.

(6) The velocity with which the air is delivered at the outer end of the delivering cylinder is in the ratio of the square root of the above excess of pressure. Inversely, the above excess of pressure is in the ratio of the square of the number of revolutions made by the blower in a given time.

(7) When the velocity of the air is suddenly extinguished, the same excess of pressure above the atmosphere is reproduced that caused the velocity.

(8) The work done by the fans upon the inflowing air is measured by the above excess of pressure per square inch, multiplied by the aggregate area of the fans in square

inches, and by the velocity of the centre of surface of the fans in feet per minute. This, however, is by no means the work done by a motor driving the blower, as such work must include, additionally, the difference between the quiescent atmospheric pressure and the pressure of the inflowing air against the back of the fans, and the friction of the motor.

(9) The work done by the outflowing air, is measured by the above excess of pressure per square inch, multiplied by the cross area of the delivering cylinder in square inches, and by the velocity of the outflowing air in feet per minute.

(10) As the velocity of the centre of surface of the fans is the same as the velocity of the outflowing air, and as the pressure above the atmospheric pressure produced by the fans upon the air is the same as the pressure producing the velocity of the outflowing air, the work done by the fans on the air, and the work done by the outflowing air, are in the direct ratio of the aggregate area of the fans to the cross area of the delivering cylinder.

(11) The number of cubic feet of air delivered per minute is measured by the cross area of the delivering cylinder in square feet multiplied by the velocity of the air issuing from that cylinder in feet per minute, and by 0·82 for the coëfficient of discharge.

(12) Of the entire quantity of air entering the blower and put in motion by the fans, one-third is first brought to rest within the blower-case, after which it is again set in motion by the fans with its original velocity.

(13) The theoretical coëfficient of the blower as a furnisher of air is two-thirds, including the air leakage; its practical coëfficient does not exceed thirty per centum.

(14) The resistance of the blower is as the square of the number of revolutions made by it in a given time. The power required to drive the blower, irrespective of the motor, is as the cube of the number of revolutions made by it in a given time.

OBITUARY.

WILLIAM PETTIT.

WM. PETTIT, deceased upon the eighth day of June, 1888, was one of the members of longest connection with the FRANKLIN INSTITUTE, having joined it in the year 1837. He was born in the year 1808, in Philadelphia County, near the village of Falls of Schuylkill, at which place he received a common-school education.

At a suitable age he entered, as one of their first apprentices, the workshops of Messrs. Mason & Baldwin, who, at that time, were engaged in the manufacture of rolls for calico printers and small machinery of a general kind. From the commencement of his apprenticeship he remained throughout the several changes of partners and of location, made by Mr. Baldwin to obtain enlarged facilities, until his final establishment at Broad and Willow Streets, and so grew up with the establishments in which he spent his business life, until an accident to his person partially incapacitated him from active pursuits.

At an early period of their connection he had won the confidence of his employer by close attention to duties, and was advanced to positions of responsibility to which he was fitted by skill and natural ability. Mechanical drawing was with him a self-acquired branch of the machinists' art, and for many years he was the chief draughtsman of the works.

During an early period of his service (1831) there was made, from descriptions of the English machines, and exhibited in motion under Mr. PETTIT'S charge, at Peale's Museum, in this city, a working model of a locomotive engine, which, from its novelty, was an attractive object to the public.

The first practical locomotive of American construction, in which Mr. PETTIT took part, was built soon after and put upon the road, and others followed a few years later. A pair of horizontal engines were built from Mr. PETTIT'S drawings and placed in a boat intended for breaking up the ice in the Delaware River to permit navigation, and for towing during the winter season.

A satisfactory trial took place in January, 1838, under Mr. PETTIT'S charge. They were the most powerful of their kind at that time, and are so justly proportioned and made to endure extremely hard service that they are still fitted for work at the present time, after a life of half a century's duration.

Mr. PETTIT was a born mechanic and possessed the excellent judgment and knowledge of detail so necessary to the full equipment of the mechanical engineer, and withal was modest and unassuming. He was one of the few to whom the country is indebted for their labors in developing from its initial state the locomotive engine.*

WASHINGTON JONES,
SAMUEL R. MARSHALL.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

HEXAMER'S FIRE EXTINGUISHER FOR MALT MILLS.

[No. 1380.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 2, 1887.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to which was referred, for examination,

HEXAMER'S FIRE EXTINGUISHER FOR MALT MILLS,

Respectfully Report: That the device consists of the application of steam under pressure as a fire extinguishing agent, which is directed through a pipe into the mill box. A stop valve outside of the box is operated by a lever held up by a weight, the weight being held suspended by a wedge or pin. To the wedge is attached a chain which is connected to a door on the side of the mill box. The force of the explosion blows open the door, which releases the wedge, causing the weight and lever attached to fall, which in turn

* Presented at the Stated Meeting of March 20, 1889. Accepted and referred for publication.

opens the valve, letting in the steam to the mill box and up through the conveyors. To check the downward passage of the fire, a set gauge controls the flow of grain in quantity, causing a bank of the material always to be in the hopper, thus resisting the force of the explosion or passage of fire downward.

The committee were aided in their investigation by being afforded an opportunity of seeing the device as attached to several breweries in our city, together with the report of successful working of the appliance when called upon.

A full description of the apparatus, with copy of letters-patent, accompanies the report.

The committee recommend the award of the JOHN SCOTT MEDAL.

[Signed.] WM. MCDEVITT,
SAMUEL H. NEEDLES,
J. M. EMANUEL.

Adopted October 5, 1887.

[Signed.] WM. D. MARKS, *Chairman.*

CONTRIBUTIONS TO THE KNOWLEDGE OF THE SUGAR GROUP. E. Fischer and J. Tafel. *Berichte*, **22**, 97 (From the *Zeit. f. ang. Chemie*).—The authors have prepared *a*-acrose, the first synthetic representative of the group of sugars belonging to the hexan series. *a*-acrose ferments under the influence of yeast and gives all the characteristic reactions of the natural sugars, dextrose, lævulose and galactose. It does not, however, affect polarized light. It would seem probable that *a*-acrose contains a normal carbon chain formed by the condensation of two molecules of glycerin aldehyde. This synthesis is the first successful step towards the artificial preparation of the more important sugars. The authors are endeavoring to obtain an optically active sugar from *a*-acrose. S. C. H.

ON SOME NEW TESTS FOR TANNIC AND GALLIC ACIDS. By S. G. Rawson (*Chemical News*, **59**, 52).—If to a solution of tannic acid, containing one part in 20,000 parts of water, a mixture of ammonium hydroxide and ammonium chloride be so added that the solutions do not mix, a white precipitate will be formed at the surface of contact. One part in 50,000 parts of water may be detected, if great care be taken. Gallic acid yields no precipitate under like conditions, but at the surface of contact a greenish ring may be observed. This coloration may be seen in solutions containing one part in 100,000 parts of water. L. B. H.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, March 19, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 19, 1889.

Mr. H. PEMBERTON, Jr., President, in the Chair.

Members present: Dr. L. B. Hall, Dr. H. W. Jayne, Dr. E. H. Keiser, Dr. H. F. Keller, Dr. Wm. H. Wahl, Prof. R. L. Chase, Prof. E. F. Smith, Dr. S. C. Hooker, Messrs Reuben Haines, T. C. Palmer, W. H. Bower, Thos. N. Newbold, C. J. Semper, Jacob Lichenheim, W. L. Rowland, F. Lynwood Garrison, W. W. McFarlan, Dr. W. C. Day, and three visitors.

The revised By-Laws, which had been laid over at the last meeting, were adopted without alteration.

The Treasurer reported that, in accordance with a recommendation made at the previous meeting, he had notified certain delinquent members of their arrears; as a result arrears were made good in one case, while in four others they were not; the Section voted that the names of the four delinquent members be dropped from the list.

Mr. F. Lynwood Garrison was elected a member of the Section.

In accordance with the new By-Laws, Section VII, the President appointed Messrs. W. W. McFarlan, W. H. Bower and the Secretary members of the committee to transact the financial business of the Section.

Upon nomination, in accordance with the revised By-Laws, Section II, the following gentlemen were elected members of the "Committee on Admissions": Dr. L. B. Hall, Dr. E. F. Smith, Dr. H. F. Keller, Dr. Wm. H. Wahl, Dr. S. C. Hooker, Mr. W. L. Rowland and Mr. C. J. Semper.

At the close of the meeting the Committee on Admissions notified the Secretary that Mr. Lee K. Frankel and Mr. A. W. Allen had been elected members of the Section.

Upon the motion of Dr. Jayne, it was voted that 250 extra copies of the revised By-Laws be printed for the future use of the Section.

Mr. T. C. Palmer then read his paper on "The Testing of Logwood Extracts."

Mr. Palmer remarked that he wished to call particular attention to the statement in his paper, that under the conditions of the test for strength of logwood extracts, with which the paper dealt, the compounds of tannin and copper oxide were nearly or quite colorless. This difference in behavior between tannin and hæmatine was the more remarkable, since in many other respects the latter acts precisely as a tannin. This is even true with respect to its action on hide powder. An attempt to estimate the tannin in a pure extract of logwood, by means of filtration through powdered hide, had resulted in an apparent showing of twenty per cent. of tannin, which loss was evidently due to an absorption of the hæmatine by the hide. In fact, the attraction of the hide for the coloring matter is quite as strong as it is for tannin. The speaker here showed a column of hide powder deeply colored by the passage through it of a very dilute clear solution of logwood.

Mr. Palmer also made some preliminary remarks on the faultiness of the tannin process of Hammer, as modified by Procter, giving data that show the amount of soluble matter in hide powder to depend very largely on the time the water is in contact with the hide, *i. e.*, in the rate of percolation. The hide powder, made by Schuchardt, gave to water an extract that left a residue on evaporation, ranging in amount, easily oxidizable, soluble in water, and with many of the reactions of the so-called coriin. The one fact above all that showed the faultiness of the process of Procter was that this residue, when redissolved in water, *was precipitated on addition of tannin solution.* Thus while the amount soluble in water could be only roughly estimated, the amount dissolved out by the tannin solution was simply unknowable, since at the top of the column, where the tannin is in abundance, there would be no dissolving out of the coriin, but as the liquor trickled down, losing tannin, it would dissolve more and more. The speaker stated that he expected shortly to bring before the Section his method of obviating this difficulty, retaining hide powder as the absorbent of tannin, but obtaining the tannin strength of the solution before and after filtration by an expedient that rendered evaporation of solutions or specific gravity determinations unnecessary.

Dr. S. C. Hooker's paper, "On a Rapid Colorimetric Method of Accurately Determining Nitrates in Potable Waters," was read by title.

Dr. E. H. Keiser read a paper "On the Redetermination of the Atomic Weight of Palladium." The following is an abstract of this paper, which was listened to with much interest, and was afterwards discussed by a number of the members present:

The atomic weight of palladium has not been determined very carefully. The only data for the calculation of this constant, at the present time, are two analyses of the double chloride of palladium and potassium, made by Berzelius in 1828. These two analyses do not agree very well. The first one gives 105·7, and the second one 106·2 for the atomic weight of palladium.

For the purpose of redetermining this atomic weight, metallic palladium in the form of foil was dissolved in aqua regia and the solution evaporated to dryness. The palladium chloride was then dissolved in dilute hydrochloric

acid and the solution was filtered. Ammonia was added to the filtrate until the precipitate, which at first formed, was redissolved. After filtering the solution again, to remove any traces of ferric hydroxide, the filtrate was saturated with hydrochloric acid gas. The palladium is thus precipitated as palladium-diammonium chloride, Pd $(NH_3Cl)_2$, a yellow crystalline compound which is insoluble in water and acids, but which is readily soluble in dilute ammonia.

The yellow precipitate was redissolved in dilute ammonia, and the solution was filtered. If any rhodium had been present in the original sample of metallic palladium, it would have been separated by this process, because the rhodium diammonium chloride is insoluble in dilute ammonia. The filtrate was thereupon treated with hydrochloric acid and the p lladium diammonium chloride, thus precipitated, was thoroughly washed with distilled water, until all ammonium chloride was removed. The compound was carefully dried over sulphuric acid in a partial vacuum.

The compound was analyzed by weighing off portions in platinum boats and heating up in a current of pure hydrogen. At a low temperature the yellow compound absorbs hydrogen, metallic palladium and ammonium chloride being formed.

$$Pd\,(NH_3Cl)_2 + H_2 = Pd + 2\,NH_4Cl.$$

On raising the heat, the ammonium chloride is completely volatilized and spongy palladium remains behind. After the boat and its contents had cooled off somewhat, the hydrogen stream was replaced by one of dry air, and the boat was allowed to cool off completely in the air. By this means i was possible to avoid the retention of hydrogen by the palladium, and as the hydrogen stream was not displaced by air until the temperature of the palladium had fallen considerably below a low red heat, it was not possible that palladium oxide should have been formed.

DETERMINATION OF ATOMIC WEIGHT OF PALLADIUM.

I.—By ignition of $PdN_2H_6Cl_2$ in current of hydrogen.

NUMBER.	Weight of Substance.	Weight of Palladium	Atomic Weight.
1, ...	·83260	·4·965	106·459
2, ...	1·72635	·86994	106·410
3, ...	1·40280	·70670	106·355
4, ...	1·57940	·79562	106·342
5.	1·89895	·95650	106·321
6, ...	1·48065	·74570	106·292
7, ...	1·56015	·78585	106·322
8, ...	1·82658	·92003	106·317
9, ...	2·40125	1·20970	106·355
10, ...	1·10400	·55629	106·400
11, ...	·93310	·47010	106·366
TOTAL, ...	16·74583	8·43606	[106·350]

Atomic weight = 106·35 H = 1· Maximum, = 106·459
N = 14·01 Minimum, = 106·292

Cl = 35·37 Difference, = ·167
Atomic weight = 106·62, when O = 16.

The foregoing table contains the results of all of the determinations that were made.

The investigation will be continued. It is intended to make a series of determinations by means of other palladium compounds.

Prof. E. F. Smith followed with two interesting papers, the first of which was entitled, "Oxidations by Means of the Electric Current," and the second, "On the Compound $C_{21}Cl_{26}$." Both papers were referred for publication in the JOURNAL OF THE INSTITUTE.

In connection with the use of the electric current in determining and separating metals, it occurred to the author that the oxidizing power of the current might be utilized to convert sulphur and other elements into higher oxides, thus securing them in forms susceptible of ready determination. Chalcopyrite was placed in a nickel crucible, containing fused potassium hydroxide. In connection with the positive pole of a battery, a heavy platinum wire from the negative pole was introduced just under the surface of the fused mass. The current was continued for ten minutes, when the contents of the crucible were dissolved out, filtered from insoluble oxides, acidified with hydrochloric acid and treated with barium chloride, when it was found that all the sulphur contained in the mineral was precipitated as barium sulphate. Comparative experiments, using the above method and also that of oxidizing with nitric acid, gave with the former method 32·35 per cent. sulphur in a specimen of chalcopyrite, and with the latter method 32·54 per cent. sulphur. The strength of the current used was one ampère.

Chromite treated in the same way as chalcopyrite yielded a little more than fifty-three per cent. Cr_2O_3 in a specimen which an older method of determination had shown to contain fifty-four per cent. Cr_2O_3.

Further experiments in this line are in progress.

The second paper, by Dr. Smith and Dr. H. F. Keller, called attention to a remarkable compound of carbon and chlorine, first produced by Dr. Smith in 1876, by the exhaustive action of chlorine on toluene exposed to sunlight, first at the boiling point and then in the cold. Analysis showed 21·41 per cent. carbon and 78·6 per cent. chlorine. The substance was crystallized from chloroform, yielding crystals measuring one-half inch in length and one-fourth inch in breadth and apparently orthorhombic.

Crystals of this compound originally melting at 152 to 153° C were preserved for twelve years, and at the end of that time no visible alteration had taken place, but on taking the melting point this was found to have changed to 101° C., at which it remained constant after recrystallization from pure chloroform. On heating a portion of the substance in a test tube hydrochloric acid was evolved; a combustion gave 22·8 per cent. carbon and 2·2 per cent hydrogen. Work is now going on to prepare the chloride again and to determine its vapor density as well as to study some of its derivatives. The authors wish to reserve this field of investigation for the present.

Dr. Jayne exhibited some specimens of commercial anthracenes. He stated that at present it is rarely made in the United States, as there was no market for any large quantity of the hard pitch which would be obtained in distilling tar for anthracene and as all produced would have to be sold

abroad, it was only made by a couple of firms, and then only when prices were high.

About twenty per cent. more of the tar was distilled off than when soft pitch was made, the distillate after cooling is filtered by means of a filter press. The resulting soft cake contains from ten to fifteen per cent. of anthracene, depending on the quality of the tar, the temperature of the oil and the pressure employed in filtering. This is then generally pressed in hydraulic presses, the percentage of anthracene then rising to about twenty-five to thirty per cent. This can be still further increased by treating with solvents, coal tar, naphtha, benzine, creosote oil, etc. The impurities partly dissolving and on re-pressing the residue an anthracene of about forty-five per cent. could be obtained. Recently it has been proposed to use as a solvent a mixture of solvent naphtha and the pyridine basis of coal tar; from such a solvent, it is said, anthracene of eighty per cent. can be obtained commercially. The process is said to be in operation in Germany in two factories.

The crude anthracene is not generally purified further by the tar distillers, but sold as such to the alizarine makers. The presence of any quantity of paraffines renders anthracene unsalable, as it interferes greatly with the subsequent treatments in the alizarine manufacture.

In England they are classed as A and B qualities.

A quality is an anthracene made from New Castle coal and is more valuable as it contains less paraffines.

B quality is made from Lancashire and Yorkshire coals, but it is customary to rate all anthracene not from New Castle coal as B quality, without further examination, for this reason American anthracene is considered of B quality.

It is sold at a certain price per unit or percentage of real anthracene it contains.

For instance, the present price in London is about thirty cents per unit per hundred-weight for A quality and twenty-six cents for B.

Therefore A anthracene of forty-five per cent. or units is worth 30×45 or $13.50 per hundred-weight and B quality $11.70.

The per cent. is generally determined by the amount of anthraquinone produced under certain conditions, the method being known as the "Hoechst" test. A weighed quantity dissolved in glacial acetic acid is oxidized by a solution of chromic acid in acetic acid. The resulting anthraquinone, after washing and drying, is dissolved in sulphuric acid of 1·88 on the water bath and, after complete solution, precipitated by water, and weighed, then burned and the resulting ash deducted.

Prof. R. L. Chase called attention to an article on the industrial use of oxygen in bleaching; he was requested to prepare an abstract of it for the JOURNAL.

Adjourned. WM. C. DAY, *Secretary.*

ON DIACETYL AND SOME OF ITS DERIVATIVES.*

BY HARRY F. KELLER.

[*A paper read before the Chemical Section at the Stated Meeting, February 19, 1889.*]

With a view to a synthetic formation of citric acid, Fittig and Daimler † subjected ethyl oxalate to the action of ethyl monochloracetate and zinc. The reaction did not take place in the desired manner, but they found among the products the ether of a dibasic, diketonic acid, which they termed ketipic (diketoadipic) acid. From the reactions of this ether it appeared highly probable that the structure of the acid must be expressed by one of the two formulæ:

$$\begin{matrix} CO,CH_2COOH \\ CO,CH_2COOH \end{matrix} \qquad \begin{matrix} CO,CH_2,COOH \\ CH_2,CO,COOOH \end{matrix}$$

It was observed that upon heating the acid was decomposed into carbonic dioxide and a yellow volatile liquid. At the suggestion of Professor Fittig I undertook the study of this reaction, in the hope of arriving at a definite conclusion in regard to the structure of ketipic acid. The former of the two formulæ given above proved to be correct: ketipic acid is readily split up into diacetyl and carbonic anhydride according to the equation:

$$\begin{matrix} CO,CH_2,COOH \\ CO,CH_2,COOH \end{matrix} = \begin{matrix} CO,CH_3 \\ CO,CH_3 \end{matrix} + 2CO_2$$

Diacetyl is the simplest orthodiketone of the fat series, a class of compounds for the production of which a great many fruitless attempts had been made. Since the discovery of its formation from ketipic acid, diacetyl has been obtained by two other reactions, viz: (1) By v. Pechmann ‡ on treating isonitroso methylactone successively with acid

* From the *Inaugural Dissertation for the Degree of Doctor of Philosophy*, Strassburg, 1888.

† *Ber.*, **20**, 202.

‡ *Ber.*, **20**, 3,162.

sulphites of the alkalies and dilute sulphuric acid, and (2) by L. Wolff,* who found that it was formed by boiling β-dibrom-laevulinic acid with water.

The constitution of diacetyl is deduced from the following facts:

(1) Its empirical formulæ is $C_4H_6O_2$.

(2) It combines readily with two molecules of phenylhydrazine, of hydroxylamine and of hydrocyanic acid. It must, therefore, contain twice the carbonyl group.

(3) As the dicyanhydrin yields dimethyl racemic acid, the two carbonyl groups must be directly united.

Preparation.—In order to obtain a sufficient quantity of diacetyl for investigation, it was necessary to prepare large quantities of ketipic ether. In the beginning the method described by Daimler † was strictly adhered to, while later it was found more convenient to prepare it according to W. Wislicenus' ‡ reaction from ethyl acetate, ethyl oxalate and metallic sodium. The ether was converted into the free acid by treating it in the cold with hydrochloric acid, saturated at 0°; small quantities of it that had escaped saponification were removed by boiling the dry powdered product with chloroform, in which the acid is insoluble.

From this acid diacetyl can be obtained either by destructive distillation, or by boiling with dilute sulphuric acid.

In decomposing ketipic acid in the dry way, it was found necessary, for obtaining a satisfactory yield of the diketone, to distil *small* quantities, not exceeding five grammes at a time and to heat rapidly. The escaping vapors and gases were passed through a U-tube, provided below with a collecting bulb, and at the farther limb with an inverted condenser. The U-tube and bulb were placed in ice. The heating is continued until white fumes cease to come off. In the receiver there collects a liquid which consists of two layers; the upper one, which is of an oily appearance, is almost

* Private Communication.

† *Inaug. Diss.*, Strassburg, 1886.

‡ *Ber.*, **20**, 590.

pure diacetyl, and the lower one an aqueous solution of it. They were separated by means of a tap funnel, and sodium chloride added to the watery solution. Diacetyl and very little water passed over first on distillation. The oily layers were then united, dried with neutral chloride of calcium and fractioned. The by far greater portion distilled over between 85° to 89°, and but a small reddish-brown residue of empyreumatic odor remained in the bulb. The distillate showed a much lighter color than the original product; it was again treated with chloride of calcium, and then distilled over completely between 87°·5 and 88°.

The decomposition of ketipic acid is also readily effected by heating with dilute sulphuric acid (1 : 10). A violent evolution of carbonic anhydride is observed when the liquid is heated to near its boiling point, and great care must be exercised in regulating the temperature in order to avoid serious losses. The aqueous distillate is treated as described above.

The yield never exceeds fifty per cent. of the theory: it is about the same for both methods.

All attempts to obtain the monocarboxylic acid of diacetyl by splitting off only one molecule of carbonic acid were unsuccessful.

Diacetyl is a mobile liquid of an intensely yellow color and characteristic odor. It boils without decomposition between 87°·5 and 88°; the vapor is greenish yellow, resembling chlorine. Its specific gravity is 0·9734 at 22°. It is soluble in four parts of water at ordinary temperature and is miscible with alcohol and ether in all proportions.

I. 0·2563 grms. gave 0·5207 grms. CO_2 and 0·1632 grms. H_2O
II. 0·2150 " " 0·4390 " " " 0·1386 " "

	Calculated for $C_4H_6O_2$	Found. I.	Found. II.
C	55·81	55·40	55·68
H	6·98	7·07	7·16

Diacetyl prepared by the reactions of v. Pechmann and of L. Wolff was found, on comparison, to be identical in every respect with that from ketipic acid.

Diacetyl shows all the reactions which are peculiar to the ketones.

It combines with the acid sulphites of the alkalies with the evolution of heat. The compound formed was not isolated, as it did not crystallize out of the solution upon standing.

When sulphurous anhydride is passed into an aqueous solution of diacetyl, its smell and color rapidly disappear; nothing can be extracted from the solution by shaking with ether. No sulphuric acid is produced by the reaction and on evaporating the liquid over sulphuric acid *in vacuo* diacetyl is regenerated. It is probable that a loose combination of the diketone with SO_2 exists, which breaks up as soon as the excess of the latter is removed.

Osazone of Diacetyl.—

$$\begin{array}{l} CH_3.C{=}N.NHC_6H_5 \\ \quad\;\; | \\ CH_3.C{=}N.NHC_6H_5 \end{array}$$

On adding 2 mols. of phenylhydrazine to the ethereal solution of 1 mol. of diacetyl, the osazone separates out on standing in the form of beautiful yellowish needles. This compound is insoluble in most of the ordinary solvents, soluble with difficulty in $CHCl_3$, somewhat more readily in acetone, and in boiling benzol. It was obtained pure by recrystallization from the latter as a light yellowish powder, melting at 239°, with decomposition.

I.	0·3017 grms	gave	0·8009 grms. CO_2 and 0·1882 H_2O		
II.	0·2213 "	"	0·5870 "	"	" 0·1401 "
I.	0·2579 "	"	46·5 cc. N at 17°·5 and 751 mm.		
II.	0·2133 "	"	39·2 cc.	" 18°	" 750 mm.

	Calculated for $C_{16}H_{18}N_2$	*Found.* *I.*	*II.*
C	72·18	72·38	72·32
H	6·76	6·93	7·03
N	21·06	21·02	21·38

Dioxim.—

$$\begin{array}{l} CH_3{-}C{=}N{-}OH \\ \qquad\;\; | \\ CH_3{-}C{=}N{-}OH \end{array}$$

This compound is formed by mixing aqueous solutions of diacetyl and of hydroxylamine hydrochloride, which has pre-

viously been neutralized with carbonate of sodium. It is precipitated white, in the form of microscopic needles. It is insoluble in water, readily soluble in alcohol and ether, and melts with partial sublimation at 234°·5. By boiling it with dilute sulphuric acid, diacetyl is again produced.

0·2380 grms. gave 0·3606 CO_2 and 0·1525 grms. H_2O
0·2278 " " 45·7 cc. N at 8° and 759 mm.

	Calculated for $C_4H_8H_2O$	*Found.*
C	41·38	41·32
H	6·90	7 11
N	24·14	24·48

A compound prepared by Schramm* in the laboratory of V. Meyer several years ago, was found to be identical with this dioxim, after a redetermination of the melting point.† It had not been analyzed.

Dicyanhydrin.—

$$\begin{array}{l} CH_3{-}C\left\langle\begin{array}{l} CN \\ OH \end{array}\right. \\ \quad\;\;\; | \\ CH_3{-}C\left\langle\begin{array}{l} OH \\ CN \end{array}\right. \end{array}$$

This is obtained by adding diacetyl to an excess of prussic acid in aqueous solution. The mixture is gently warmed for some time and then extracted with ether. On evaporation of the latter, the nitrile remains in the form of colorless needles or prisms, united to peculiar dendritic shapes. It is soluble in water, alcohol and ether, insoluble in all other solvents. It is very hygroscopic and decomposes when heated with water. It melts at about 110°.

0·3189 grms. dried in the desiccator gave 57·9 cc. N at 19° and 734 mm.

	Calculated for $C_6H_8N_2O_3$	*Found.*
N	20·00	20·58

Dimethylracemic Acid.—

$$\begin{array}{l} CH_3{-}C\left\langle\begin{array}{l} COOH \\ OH \end{array}\right. \\ \quad\;\;\; | \\ CH_3{-}C\left\langle\begin{array}{l} OH \\ COOH \end{array}\right. \end{array}$$

* Schramm, *Ber.*, **16**, 179.

† Private communication of Professor Meyer to Professor Fittig.

Strecker* has observed that racemic acid is formed upon boiling glyoxal, prussic acid and dilute hydrochloric acid. It was, therefore, to be expected that diacetyl, under similar conditions, would give dimethylracemic acid.

An acid of the composition $C_6O_6H_{10}+H_2O$, and whose properties closely resemble those of racemic acid, was obtained by slightly modifying Strecker's method. It was prepared in the following manner: The finely powdered crystals of the hydrocyanide were placed in a small flask and covered with concentrated hydrochloric acid; it passed slowly into solution, but on standing, colorless crystals were observed to separate; they probably represent the acid amide. No attempt was made to determine their character, but the mixture was first heated and then the hydrochloric acid evaporated on the water bath; the residue was dissolved in water and the solution divided into two equal parts. Of these one was exactly neutralized with K_2CO_3, and boiled; the other portion was then added. Upon cooling, the acid potassium salt—which, like that of tartaric acid, is difficultly soluble—crystallized out. This was recrystallized, then converted into the neutral salt and the solution of this precipitated with acetate of lead. The lead salt was washed with water, dried, pulverized, and then suspended in water and decomposed with hydrogen sulphide. On evaporating the filtrate, the new acid crystallized out in large, shining prisms and plates. These have the habitus of crystals of racemic acid. They contain 1 mol. of H_2O, but do not effloresce in the air. The acid is readily soluble in water and in alcohol, insoluble in ether.

0·2494 grms. of air dry acid gave 0·0227 grms. loss and 0·3361 CO_2 and 0·1177 CO_2

	Required for $C_6H_{10}O_6 \cdot H_2O$	Found.
C	36·73	36·75
H	5·10	5·24
H_2O	9·18	9·10

The anhydrous acid melts at 180°; it is decomposed at this temperature. Heated on platinum foil, it is decom-

‡ *Zeitschrift f. Chem.*, 1868, 216.

posed and completely volatilized without leaving a trace of carbon.

Böttinger* has described, as dimethyltartaric acid, an acid which he obtained as a side product by the action of zinc upon an alcoholic solution of pyruvic acid. It showed no tendency to crystallize, undoubtedly because it was impure; its salts are certainly identical with some of those described below.

Potassium Salts.—The neutral salt is obtained from the acid one by exact neutralization with potassium carbonate. It is quite soluble in water, and crystallizes in needles.

The acid salt, $C_6H_9O_6K$, the preparation of which has been described above, is readily soluble in hot water, sparingly in the cold. It crystallizes in crusts or little plates. It contains no water of crystallization.

0·2526 grms. gave 0·1008 grms. K_2SO_4.

	Required for $C_6H_9O_6K$	*Found.*
K	18·05	17·92

Calcium Salts.—$C_6H_8O_6Ca + 1\frac{1}{2}$ HO.† Chloride of calcium throws down from solutions of the neutral salts of the alkalies a white crystalline precipitate, insoluble in water and acetic acid.

0·2653 grms. lost on heating to 215–220° 0·0282 grms. H_2O, and gave 0·1483 grms. $CaSO_4$.

	Calculated for $C_6H_8O_6Ca + 1\frac{1}{2}H_2O$	*Found.*
H_2O	11·11	10·64
Ca	16·46	16·43

Barium Salt.—$C_6H_8O_6Ba + H_2O$. Although quite as insoluble as the calcium salt, this is not precipitated immediately by barium chloride or acetate, it separates out completely, after some time, in the form of small needles, which

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Annalen*, **188, 315.

† Both the Ba and Ca salt were dried in the desiccator before they were analyzed; for this reason the Ba salt was found to contain less H_2O than Böttinger determined.

are generally grouped around a common centre. It contains 2 mols. of water, which are driven off at 160°.

0·2046 grms. gave 0·0211° loss and 0·1364 grams $BaSO_4$.

	Required for $C_6H_8O_6Ba \cdot 2H_2O$	Found.
Ba	39·25	39·19
H_2O	10·32	10·31

The lead salt is precipitated in the form of a voluminous precipitate on adding lead acetate to the neutral potassium salt solution. It is likewise insoluble in water and in acetic acid. From acid solutions it is obtained in small needles.

In addition to the reactions described, the solution of potassium dimethylracemate gives the following: $ZnSO_4$ produces a white amorphous precipitate, insoluble in water and dilute acetic acid. $AgNO_3$ in concentrated solutions gives a white curdy precipitate. With ammoniacal silver solutions a metallic mirror is formed, especially on warming.

$HgCl_2$ throws down a white precipitate.

$CuSO_4$ is colored deep blue by the solution; the liquid remains clear on adding alkalies.

Ferric chloride produces a voluminous yellowish brown precipitate.

Halogen Derivatives of Diacetyl.—Bromine acts upon diacetyl but slowly in the cold; on warming two atoms of hydrogen are replaced. Dibromdiacetyl is best prepared by adding bromine dissolved in CS_2 or $CHCl_3$ to a similar solution of the diketone, until the red color no longer disappears on heating in the water bath. The solvent is then distilled off and the residue repeatedly crystallized from carbon disulphide and from petroleum ether. Thus obtained it forms yellow leaflets of a waxy lustre, melting at 117°. It is soluble in ether, carbon disulphide, chloroform and petroleum ether.

I. 0·2 grms. gave, after treating with Na amalgam, 0·3083 grms. AgBr.
II. 0·2 " " " boiling " Na_2CO_3 solution, 0·3079 grms. AgBr.

	Calculated for $C_2H_4Br_2O_2$	Found. I.	Found. II.
Br	65·57	65·59	65·51

It is probable that the two atoms of bromine are

attached to two *different* carbon atoms, as the action of Br does not seem to proceed any further, even when a large excess is added.

Monochlordiacetyl.—By the action of chlorine upon diacetyl in the sunlight, a thick oily liquid, possessing the color of diacetyl and a pungent smell, was obtained, it did not crystallize at — 12°. Its boiling point is about 150°. Sodium carbonate solution decomposes it, especially on heating.

0·5656 grms. gave, after treating with Na_2CO_3, 0·6566 grms. AgCl.

	Required for $C_2H_3O_2Cl$	*Found.*
Cl	29·46	28·72

The further study of the halogen derivatives of diacetyl is being proceeded with.

Metallic Compounds.—When diacetyl is added to a solution of silver nitrate with *just* enough ammonia to hold the oxide of silver in solution, metallic silver is precipitated, sometimes as a mirror upon the glass; if on the other hand a large excess of ammonia be used, a voluminous white precipitate is formed, even in extremely dilute solutions of the diketone. A similar precipitate forms in ammoniacal solutions of cuprous chloride.

After drying them at 100°, these substances were analyzed with the following results:

Ag compound:

I. 0·234 grms. gave 0·2874 CO_2 and 0·892 H_2O and 0·1153 Ag.
II. 0·2368 " " 0·2898 CO_2 and 0·0923 H_2O
III. 0·294 " " 0·1442 Ag

	Required for $C_6H_9N_2Ag$	*Found.* I.	II.	III.
C	33·18	33·46	33·37	
H	4·14	4·23	4·33	
Ag	49·77	49·28		49·04

Copper compound:

I. 0·2123 grms. gave 0·3216 CO_2 and 0·1030 H_2O
II. 0·4335 " " 58·6 cc. N at 15·5° and 755 mm.
III. 0·2008 " " 0·091 CuO

	Required for $C_6H_9N_2Ag$	*Found.* I.	II.	III
C	41·86	41·39		
H	5·23	5·35		
N	16·27		16·32	
Cu	36·62			36·14

These compounds are quite stable; at high temperatures they are decomposed with formation of acetamide.

They are evidently salts of the trimethyl glyoxaline, discovered by v. Pechmann.* This was proved also by preparing the hydrochloride of the base, by decomposing the salts with hydrochloric acid and evaporating the filtrate. The residue was recrystallized from alcohol-ether.

0·2275 grms. gave 0·2219 AgCl

	Calculated for $C_6H_{10}N_2 HCl$	Found.
Cl	24·38	24·13

The free base was liberated with sodium carbonate and extracted with ether. Recrystallized from a mixture of ether and ligroin, it forms small white needles which have a bitter taste and melt at 130 or 131°.

ON THE COMPOUND $C_{21}Cl_{26}$.

By EDGAR F. SMITH and HARRY F. KELLER.

[*Read at the Stated Meeting of the Chemical Section, March 19, 1889.*]

In 1876,† one of us (S.) described a compound, containing only carbon and chlorine. It was obtained by the exhaustive chlorination of toluene exposed to sunlight, first at the boiling temperature and then in the cold. Several analyses of the purified product showed the presence of 21·40 per cent. carbon and 78·6 per cent. chlorine. The only solvent employed at the time was chloroform, and from such a solution crystals, measuring one-half inch in length and one-fourth inch in breadth, were obtained. The forms were apparently orthorhombic. The melting point, taken after each of a series of re-crystallizations, remained constant at 152°–153° C. To this rather interesting derivative the improbable formula $C_{21}Cl_{26}$ was ascribed. Nascent

* *Ber.* **21**, 1411.

† *Dissertation.* Goettingen, 1876; *Jahresbericht*, 1877, p. 421; *Am. Phil. Soc.*, **17**, p. 29.

hydrogen acted with difficulty upon it. After an exposure of two months to the influence of zinc and sulphuric acid, it was scarcely changed, inasmuch as an analysis of the product gave 21·69 per cent. carbon, 77·76 per cent chlorine and one per cent. hydrogen.

Nothing further was done with the compound until about five years later, when a portion of it was treated in a sealed tube with an excess of aniline (*Am. Chem. Jour.*, vol. 1, p. 150). By this treatment a base was formed, melting at 230° C. Its hydrochloric acid salt was analyzed.

Crystals of the original compound, in its purest condition, were preserved for twelve years without undergoing any visible alteration, and it was but natural that we should be surprised, on fusing some of this same material, to find it melting at 101° C. This melting point remained constant, even after re-crystallization from pure chloroform. On heating a portion of the substance in a test tube, we observed that hydrochloric acid gas was evolved. A combustion gave 22·8 per cent. carbon and 2·2 per cent. hydrogen. A vapor density determination was carried out, but as we had evidence of decomposition, we place no reliance on the result. Every possible precaution was observed in the combustion, in order that we might arrive at the true hydrogen percentage, and that given above would indicate but slight change from the original constitution. Work is now being prosecuted, with a view of obtaining the carbon chloride, when it is proposed to pay especial attention to the solution of its molecular formula and to the study of some of its derivatives. We, therefore, request those who may have entertained the idea of investigating this compound to postpone their work, and leave the field to us at least for a few months.

University of Pennsylvania,
Philadelphia, March 15, 1889.

OXIDATIONS BY MEANS OF THE ELECTRIC CURRENT.

By Edgar F. Smith.

[*Read at the Stated Meeting of the Chemical Section, March 19, 1889.*]

In using the electric current for the determination and separation of metals, it occurred to me that its oxidizing power might be utilized to convert sulphur and other elements into higher oxides, thus bringing them into forms in which they could be readily determined. To test this I undertook the oxidation of the sulphur in chalcopyrite after the following manner: About ten grammes of solid potassium hydroxide were placed in a small nickel crucible, and carefully heated over a Bunsen burner until the water was expelled, when the flame was reduced, so that its heat was just sufficient to retain the alkali in liquid form. The crucible was put in connection with the positive pole of a battery, and the powdered mineral placed upon the alkali. A heavy platinum wire, from the negative pole, extended just under the surface of the fused mass, and when the current was passed, a lively action ensued, accompanied with considerable spattering. Loss was prevented by placing a perforated watch crystal over the crucible. When the action had continued for ten minutes the connection was broken, the crucible and its contents allowed to cool, placed in a beaker, covered with water and warmed upon an iron plate. On filtering off the insoluble oxides, the filtrate was blue in color, due to a little copper. The liquid was acidulated with hydrochloric acid, and care taken to detect any hydrogen sulphide or sulphur dioxide, which are always present, when the oxidation of the sulphur is incomplete. In this particular case all the sulphur was changed to sulphuric acid, and removed as barium sulphate. When ignited the latter presented a perfectly white appearance, showing not the slightest trace of iron.

Having succeeded so well with the first portion I weighed

off ·1734 gramme chalcopyrite, subjected it to a like treatment, and obtained ·4086 gramme $BaSO_4$ = ·0561 gramme S or 32·35 per cent. S. One of my students oxidized another portion (·5 gramme) of the same material with nitric acid and potassium chlorate, and obtained 32·54 per cent. sulphur.

The current used above registered one ampère (10·45 cc. H-O gas) per minute as it passed through the fused alkali. The solution containing the potassium sulphate contained no iron. A little copper was present in it. The residue of oxides (Fe_2O_3, CuO, etc.) should dissolve readily and completely in warm hydrochloric acid. There may, however be a residual mass, red in color, but this can be disregarded, as it is only metallic copper. In some of the oxidations the wire attached to the negative pole was coated red by copper, or with a black deposit of metallic iron. The idea suggested itself to me that, as the metal was depositing as such, it might possibly inclose some mineral, as yet unacted upon, and thus withdraw it from the field of oxidation. I therefore invariably, in every determination, reversed the current for a few minutes before its final interruption. This seems to have been unnecessary with chalcopyrite, but was required with some other minerals with which similar experiments were tried.

With a chalcopyrite, different from that analyzed before, the following percentages of sulphur were obtained :—

(1) 29·9 per cent S—(2) 30·11 per cent S—(3) 29·7 per cent S.

The quantity of mineral used was in (1) ·1528 gramme, in (2) ·1445 gramme and in (3) ·1082 gramme. About 10 grammes of potassium hydroxide were used in each determination. The current was one ampère, acting for a period of ten minutes. In working with a quantity of mineral varying from ·2 — ·3 gramme, the quantity of alkali should be doubled.

This method affords a rapid oxidation of sulphur to sulphuric acid, so that the inconveniences arising from the slow, time-consuming method with nitric acid and potassium chlorate, or that with nitric acid alone, can be avoided, where a current of the strength indicated above can be obtained.

Iron salts also are removed. I have endeavored to oxidize the sulphur of pyrite by this means, but thus far the experiments have been fruitless. I have not obtained more than half of the sulphur in the form of sulphate. Even when the current acted for thirty minutes, the result was no better. The cause of this singular behavior appears to be due to the presence of the iron. I expect, however, to so modify the experiment in this case that pyrite may yet be as easily oxidized as chalcopyrite.

As time permits, this mode of oxidation will be extended to other natural sulphides and to compounds containing sulphur.

My experiments in oxidizing with the current really began with chromite. It was treated the same as the chalcopyrite. Twice I obtained a little over fifty-three per cent. Cr_2O_3 from a specimen of this mineral, which by an older method gave fifty-four per cent. Cr_2O_3. At present I am not prepared to say anything more in regard to this mineral. Some difficulties have appeared which require solution before entering into details.

Nickel crucibles as well as iron have been used in this work, and with chromite an old platinum vessel was made to do service. The crucibles were one and one-fourth inches in height, and one and three-eighths inches wide; the most convenient form would be that measuring two inches in length, and one and one-half inches in width.

In closing I must extend my sincere thanks to Mr. D. L. Wallace, of this laboratory, for his kind assistance, without which it would have been impossible for me to carry out these experiments at this time.

University of Pennsylvania,
Philadelphia, March 19, 1889.

DISCUSSION.

Mr. Pemberton.—The application of the electric current as an oxidizing agent in chemical analysis is certainly most interesting. So far as the particular application to the analysis of pyrite is concerned, the process would be open

to the objection brought forward by Dr. Lunge to other methods of analyzing by alkaline fusion. Sulphur, present in combination (as in galenite or barite), would be reckoned available for sulphuric acid manufacture. This, however, relates to only one use of the process and is of minor importance. The principle involved is of wide application, and is a new and interesting departure in chemical analysis.

The TESTING of LOGWOOD EXTRACTS.

By T. Chalkley Palmer.

[*Read at the Stated Meeting of the Chemical Section*, Franklin Institute, *March 19, 1889.*]

The continued paper of Dr. Bruehl, now appearing in the *Textile Colorist*, on "Dyewood Extracts, etc.," while of great importance and generally very practical, contains some statements that may be challenged. This is noticeably the case when the author discusses Trimble's method of estimating the tinctorial value of logwood extracts. The description of this method, given on page 5 of the January issue, is in outline correct, but some particulars of an essential nature are not given, and the capabilities of the process are certainly misapprehended.

In order to operate successfully with this test, the following conditions must be observed. The bluestone or copper-sulphate solution, as well as the solution of extract, must be made with distilled water. The water used for dilution in the graduated cylinders, if pure distilled water, will give a reddish-purple color, quickly fading, and useless for a standard of comparison, even during ten minutes. If river or hydrant water is used, the precipitate forms into flocks immediately, and settles to the bottom of the cylinder, being likewise useless. It has been found, in practice, that the water for dilution should be three-fourths distilled water and one-fourth hydrant water. The explanation of this necessity for a certain amount of ordinary water is not, so far, at all clear; but probably a trace of ammonia, or still

more a trace of lime, is necessary to the production of the blue, finely divided lake of logwood and copper oxide. The quantity of the blue compound is, however, so minute that the slightest excess of this agent, be it what it may, produces results akin to over-oxidation.

It would, of course, be more scientific to take pure distilled water, and add enough of the needed reagent, whatever it may be, to produce the result; but the nature of this reagent not being known, and a mixture of water, as given above, producing good results, I have contented myself with this process. It only needs to be further pointed out, that as natural waters vary, varying proportions may have to be used in different places. The above proportions are for Schuylkill water.

In comparing two cylinders by this process, instead of looking at the two from above, as stated by Dr. Bruehl, it is necessary to look at them from the side; in fact, in a direction at right angles to the length of the cylinders. It is a good plan to cut off the view of the meniscus with a piece of paper or with the hand, thus leaving visible for comparison two bands of color, not complicated with any inequalities. If one looks into the tops of the cylinders, and if he has in one a standard diluted to 100 cc., and beside it an adulterated extract diluted to 50 cc., he is then comparing two columns of color, of equal richness, to be sure, but of which one is twice as deep as the other. It is very evident that this would lead to a serious error. If, on the other hand, he compares these two cylinders by a side view, he is looking through two columns of equal thickness. By this method of procedure he can get results accurate within two per cent. The description of the method has been already given pretty fully elsewhere, and though it may appear complex, is really very expeditious.

Now, in regard to the conclusion of Dr. Bruehl, that tannin-bearing matters have a disturbing effect on this reaction and that wrong values will consequently be obtained for extracts adulterated with hemlock, chestnut, etc., it is to be said that this is altogether erroneous. After a rather extensive experience in using this method, I have

perceived very clearly that it constitutes a laboratory assay rather than a dye-house test; that is, it shows more concerning the purity and the mode of manufacture of an extract of logwood than it does of its practical and effective value in the dye-house. Let me make this clear, and in doing so, it will be perceived that what the method lacks in one respect it gains in another.

Everybody knows that hemlock, chestnut, and still more cutch and sumac, are not absolute and unqualified adulterants when considered from the dyer's point of view. Most warp and other cotton-dyers habitually add cutch and hemlock to their dye-baths, either knowingly and avowedly or unknowingly under various fancy names. The *rôle* of these materials is two fold: they act as real coloring matters, producing colored lakes with the metallic salts used in dyeing, and they serve as "fasteners" or accessory mordants, aiding the ultimate color to withstand washing operations that follow dyeing. This is very ancient history. Consequently, it is far from surprising that any one who has not used Trimble's method should suppose that an equivalent result would be obtained here; that the tannins present in the extracts in question would help to form colored lakes; but it is difficult for the writer of these lines to understand how anyone can think so who has done more than meditate on the subject.

The facts in the case are these. If you weigh out three equal quantities of a given extract of logwood, and if you add to one of these an equal weight of glucose, and to another an equal weight of hemlock extract, and test the three against each other, you will get, using the pure extract for standard at 100 cc., for the one mixed with glucose, 50 cc., and for the one mixed with hemlock, almost exactly the same, but possibly 51 cc. or 52 cc., It is evident from this, that any lake produced by the union of the hemlock tannin and the copper oxide is, under the peculiar conditions of this test, colorless or nearly so. Why this should be so here, and not so under the conditions that obtain in the dye-house, it is not easy to explain, but there is no room for dispute concerning the facts.

The following results will bear out this statement of the case, being selected from many others obtained by this method on account of their bearing on the point at issue.

	Description of Extract.	Observed Dilution.	Theoretical Dilution.
		cc.	*cc.*
1	Extract logwood, 100 per cent. (Standard), ...	100·0	. . .
2	" " 85 " : Extract hemlock, 15 per cent.,	86·0	85·0
3	" " 80 " : " " 20 "	79·0	80·0
4	" " 75 " : Glucose, 25 "	75·0	75·0
5	" " 70 " : " 30 "	69·5	70·0
6	" " 66·6 " : Extract chestnut, 33·3 "	65·5	66·6
7	" " 65 " : Cutch, 25 per cent.; glucose, 10 per cent., ...	64·0	65·0
8	" " 50 " : Molasses, 50 per cent., ...	48·0	50·0
9	" " 33·3 " : " 66·6 "	33·0	33·3

It is evident that we have in this method the nearest approach to a scientific assay of logwood so far devised. By means of it we arrive at the absolute amount (roundly speaking) of logwood extract in any given sample, let the adulterant be any one or two of the substances mentioned in the above table. No doubt many things might be added to an extract of logwood that would interfere with this test, but none of the ordinary adulterants appear to do so.

Finally, the method appears capable of extension in certain directions, whereby its scientific value may be increased very greatly. If this extension proves practicable, further communication will be made concerning it.

ABSTRACTS.

On the Volumetric Determination of Sulphur by Means of Baric Chloride. C. and J. J. Beringer (*Chemical News*, **59**, 41) find this method satisfactory, if acetic acid (10 cc.) and sodium acetate (10 grammes) be added to the solution of the sulphate. The presence of free mineral acids, or of nitrates and chlorides is not objectionable, provided enough sodium acetate be added to convert all into sodium salts. L. B. H.

Commercial Production of Oxygen.—At the Stated Meeting of the Chemical Section, held March 19th, Prof. R. L. Chase made the following remarks on the commercial production of oxygen: In the *Journal of the Society of Chemical Industry*, of February 28th, there is an interesting article on "Some Industrial Applications of Oxygen." It is claimed that the gas can be manufactured in London at a cost of not over 7*s.* 6*d.* per 1,000 cubic feet.

In bleaching with chloride of lime, it was found that the addition of oxygen not only accelerated the bleaching process, but also reduced the amount of bleach necessary. Some laboratory experiments with paper pulp showed a saving of from forty to fifty per cent. in the amount of bleach necessary. A practical experiment in the large way, and carried out under somewhat disadvantageous conditions, showed a saving of thirty per cent. in bleach.

The bleaching power of free chlorine was also very largely increased by the addition of oxygen.

In the purification of illuminating gas from sulphur compounds, it was found that by the addition of oxygen the lime purifiers alone were sufficient to remove all sulphur compounds, and that the lime could be used nearly twice as long as usual. Also that the luminosity of the gas was slightly increased instead of there being a decrease, as is the case when air is used.

For the maturing of spirits, it was found that by the addition of oxygen at a pressure of one or more atmospheres for ten days, the spirits were mellowed to an amount equal to that produced by three to five years' ageing. The amount of fusel oil was also largely reduced.

RESEARCHES ON SILICIUM AND BORON.—Ludwig Gattermann, *Berichte*, **22**, 186.—The author prepares silicium by heating together powdered magnesium and powdered quartz.

$$SiO_2 + 2\ Mg = Si + 2\ MgO$$

The various silicium preparations can be made from the grayish-black reaction product. If it be desired to prepare crystallized silicium, the crude silicium is heated in a luted crucible with zinc, care being taken that the temperature remains below the boiling point of the latter. By treating the fused mass with hydrochloric acid the zinc is dissolved, and steel-blue needles of silicium are obtained.

Boron may be similarly obtained by heating borax with powdered magnesium. After washing with water and then with hydrochloric acid, the residual brownish-gray powder consists mostly of boron, which may be obtained beautifully crystallized by fusion with aluminium. S. C. H.

BOOK NOTICES.

THE ANIMAL LIFE OF OUR SEA-SHORE; WITH ESPECIAL REFERENCE TO THE NEW JERSEY COAST AND THE SOUTHERN SHORE OF LONG ISLAND. By Angelo Heilprin, Professor of Invertebrate Paleontology and Curator in Charge Academy of Natural Sciences of Philadelphia, etc. Philadelphia: J. B. Lippincott Co., 1888,

Professor Heilprin, in this little book, has added another to his series of handy volumes for the use of that sojourner on our sea-coast, who has an idea above the Monmouth races, the occasional "hops," and the distractions of billiards and poker. Even to those who are ardent deep sea fishermen, the

book proves most interesting, although the subject is rather the jetsam of the ocean on its shore. The description of the strange and often mutilated remains, which one finds on the beach, is given in clear and simple language, and the numerous illustrations are generally satisfactory and well chosen. If a criticism might be ventured here, it would be that printer's ink has been unequally and often too largely used in printing the cuts. This apart, the little book ought to have a large sale, as it is in good form for the pocket, well conceived and interesting. F.

ELEMENTS OF MACHINE DESIGN, NOTES AND PLATES, FOR THE USE OF STUDENTS IN LEHIGH UNIVERSITY. By J. F. Klein, Professor of Mechanical Engineering. The Comenius Press, Bethlehem, Pa.

Fortunately the preface of this book states that it is not a complete treatise, even on the machine parts represented, frequent reference to the larger works of Reuleaux and Unwin being desirable.

There are fourteen plates, which form the sub-divisions of the text.

Plate I treats of different kinds of screw threads, giving formulæ for proper diameter for given working load when used for fastenings, for steam tight joints and for transmitting motion, together with proportions for the various standard threads in use.

Plate II gives different kinds of bolts, with methods of locking the nuts in place. The proportions are good, except as to chamfering. The round heads of the screws are too small in proportion to the bodies. This plate is not up to modern standards and omits many important points.

Plate III treats of rivets and riveted joints and gives standard formulæ.

Plate IV gives examples of and formulæ for joints for connecting plates not in the same plane.

These two plates on boiler work are such a mere skeleton of the subject that in many cases a student would have to refer to Rankine or Reuleaux to obtain a clear understanding.

Plate V treats of keys and methods of fastening hubs to shafts and shafts in sockets, and also straps to ends of connecting-rods. The formulæ are entirely unexplained, and the rationale of the subject not touched upon.

Plate VI treats of methods of drawing the curves of gear teeth, and is very unsatisfactory. It is based on the theory of axoids and centroids, as explained by Reuleaux, but to anyone not thoroughly acquainted with Reuleaux's work these chapters would be of little use. The different shapes of teeth, their advantages and disadvantages and methods of describing the exact and approximate curves are only partially explained. This matter covers thirteen pages of texts, while twenty pages of the same chapter are devoted to a method of "Profiling of Teeth by Rectangular Co-ordinates," which has been devised by the author. The first sentence states that "this method is at once the simplest and most exact, involving only capacity to use the square and to lay off distances accurately." Some conception of the extent of the capacity which is "only" thus involved may be obtained by examining the first figure, which is given on page 51. This is the profile of the tooth of

a rack, the diametral pitch of which is two, or about one and one-half inches, actual pitch. In the first place, this is a relatively large pitch, the great majority of gears to be cut or for which patterns are to be made in ordinary practice having much smaller pitches than this. But, taking this rack tooth of one and one-half inches pitch, the requirements of this "simplest and most exact" system are that eight lines shall be drawn parallel to and on each side of the pitch line at a distance apart of 0·075 inches, and that the following distances from the radial reference line be laid off on these lines consecutively: ·008″, ·023″, ·042″, ·065″, ·092″, ·122″, ·155″ and ·191″.

The claim that this method is simple and exact, in view of the extreme difficulty of laying off the above dimensions for this relatively large pitch, is preposterous, even when the figures are already selected; but when, in addition to this, great judgment and care have to be exercised in selecting the proper figures from the proper table, the liability to error becomes so great that one would never feel confident of the result without verifying it by one of the simple and exact methods in general use.

Plate VII continues the subject of spur gearing, quoting Reuleaux, Rankine and Willis, and giving formulæ for proportions and strength. It is to be regretted that the author did not devote the ability and perseverance displayed by his tables of co-ordinates, to the making of tables of ultimate strength for gear teeth. Such tables are greatly needed to enable engineers and designers to avoid the constantly recurring calculations to determine the pitch and length of face of tooth required to stand a given stress at the pitch line.

This chapter also gives proportions for shafts, arms and wooden teeth and treats of equidistant values of cutters, but maintains the general air of obscurity and mystery which pervades the book.

Plate VIII, "Problems in Gearing" is good. It contains information and is capable of imparting instruction to any student who has been sufficiently prepared to receive it, although such preparation could not be obtained from this book.

Plate IX, on "Bevel Gearing," is also very good, although to anyone not already well up on the subject, it would prove rather difficult to understand.

The author adheres to the old idea of the necessity of a "Hunting Tooth," and would sacrifice the accuracy and simplicity of the velocity ratio to gain such a tooth.

Plate X on "Worm Gearing," begins with an obscure reference to hyperboloidal wheels and screw gearing which had better have been omitted. Even the part on "Worm Gearing" is more notable for what it omits than for what it gives.

Plate XI on "Belt Gearing" follows closely Reuleaux' presentation of the subject, and gives much useful information very concisely.

Plate XII, gives an original, complete and scholarly treatment of the subject of cone pulleys, with formulæ and extensive tables for determining the diameters required to secure equal tension of the belt on all the steps of the cones. This, however, is a refinement which is rarely called for, because the distance between centres of the pulleys should, if possible, be kept great

enough to secure efficient and satisfactory working of the belt, and, if this is done, the change of length of the belt, due to its angularity, will be inconsiderable.

Plate XIII, on rotating pieces, is good.

Plate XIV, on bearings, is misleading in its condemnation of cast-iron bearings and its advocacy of universal babbitting, and does not by any means cover the ground it should. The part on connecting rods, however, is good.

Taking the book as a whole, it is difficult to see the benefit of it to anyone, excepting local students who have been trained in a certain manner and up to a certain point.

It may be valuable as "Notes for the use of Students in Lehigh University," but is not so as a treatise on the "Elements of Machine Design."

W. H. T.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Agricultural Experiment Station, Auburn, Ala. Bulletin No. 3, new Series.
From the Station.

Alabama Railroad Commissioners. Eighth Annual Report for year ending June 30, 1888.
From the Commissioners.

American Public Health Association. Report of the Committee on the Pollution of Water Supplies.
From the State Board of Health of Michigan.

American Institute of Mining Engineers. Eight pamphlets, subject to revision.
From the Institute.

Atlanta. Fourteenth Annual Report of the Board of Water Commissioners for the year 1888.
From the Board.

Boston Water Board. Report of the Water Meter Testing Commission.
From the Board.

California State Mining Bureau. Eighth Annual Report of the State Mineralogist.
From the Bureau.

Cincinnati Public Library. Bulletin of books added during 1888.
From the Library.

Cincinnati Water Department. Forty-seventh and Forty-eighth Annual Reports for 1886 and 1887.
From the Department.

Columbus Water Works. Annual Report. 1882–83. From the Works.

Dakota School of Mines. Preliminary Report upon the Geology, Mineral Resources and Mills of the Black Hills of Dakota.
From Franklin R. Carpenter, Dean.

Dayton, O. Annual Reports of the Water Works Trustees 8th, 16th, 17th and 18th for 1877, 1885, 1886 and 1887.
From the Water Works.

Department of Agriculture, U. S. Botanical Division. Bulletin No. 8.
Division of Entomology. Periodical Bulletin, No. 8.

Department of Agriculture, U. S. Report of the Statistician. No. 59.
From the Department.

Engineer Department, U. S. A. Annual report upon the improvement and care of the public buildings and grounds in the District of Columbia and Washington aqueduct. 1875 and 1878.
Annual reports upon the Washington aqueduct, increasing water supply of Washington and erection of fish-ways at the Great Falls of the Potomac. 1885 to 1888.
From Major G. J. Lydecker, in charge.

Engineer Department, U. S. Annual reports of O. E. Babcock, John M. Wilson (and others) upon the improvement and care of the public buildings and grounds in the District of Columbia. 1872, 1874, 1876, 1880 to 1888.
From Col. John M. Wilson.

Engineers' Society of Western Pennsylvania. Ninth Annual Meeting and Three Papers. From the Society.

Erie, Pa. Annual Report of the Board of Water Commissioners for 1886 and 1887. From the Board.

Fall River, Mass. Fifteenth Annual Report of the Watuppa Water Board to the City Council. January 1, 1889. From the Board.

Fletcher, Alice C. Indian Education and Civilization. Senate Executive Document. 1885. From the Department of State.

Franklin Machine Works. Catalogue of Machinery. From H. P. Feister.

Frazer, Persifor. Archæan Characters of the Rocks of the Nucleal Ranges of the Antilles. From the Author.

Friends' Free Library, Germantown. Report for 1888. From the Library.

General Land Office, U. S. Annual Report of the Commissioner. 1885 to 1888, inclusive. From the Office.

General Society of Mechanics and Tradesmen of the City of New York. Annual Report. From the Secretary of the Society.

Geological and Topographical Map of the New Boston and Morea Coal Lands in Schuylkill County, Pa. From Benj. S. Lyman.

Germanischer Lloyd. Internationales Register. 1888 and 1889.
From L. Westergaard & Co.

Harris-Corliss Engine. Catalogue.
From the W. A. Harris Steam Engine Company.

Hartford, Conn. Report of W. E. Worthen, upon an additional supply of water. March, 1864.
Report relative to new reservoir. 1878.
Reports on supply of water from Farmington River. 1878.
From the Hartford Water Works.

Hartford Steam Boiler Inspection and Insurance Company. Some Recent Boiler Explosions. From the Company.

Hydrographic Office, U. S. Nautical Monograph No. 5. The Great Storm off the Atlantic Coast of the United States. March 11–14, 1888.
From Lieut. G. L. Dyer.

Idaho. Reports of the Governor to the Secretary of the Interior. 1885 to 1888.
From the Governor.

Iowa State Board of Health. First to Fourth Biennial Reports. 1881 to 1887. Monthly Bulletins. Vol. 1. Nos. 3, 5, 7, 9, 11, 12. Vol. 2. Nos. 1 to 7. 1888.
From the Board.

Ives, F. E. A New Principle in Heliochromy. From the Author.

Kansas State Board of Agriculture. Advance Sheets Sixth Biennial Report.
From the Board.

Landis, C. K. Map of the Proposed Grand Avenue to the Park.
From C. K. Landis.

Leominster, Mass. Sixth, Seventh, Eighth, Twelfth to Sixteenth Annual Reports of the Water Board for years ending March 1878 to 1880, and 1884 to 1888.
From the Board.

Levytype Company of Philadelphia. Specimen Sheets.
From the Company.

Locomotives. Six charts illustrating types of European and American locomotives, between the years 1771 and 1882.
From Wm. Kite, Librarian Friends' Library.

Lynn. Seventeenth Annual Report of the Public Water Board for 1888.
From the Board.

Madison, Wisconsin. Sixth Annual Report of the Board of Water Commissioners, for year ending October 1, 1888. From the Board.

Making of a Paper. Patents. From the W. J. Johnston Company.

Manchester (England) Free Public Libraries. Hand-book, historical and descriptive. From the Librarian.

Manchester (England) Statistical Society. The free library movement in Manchester. By W. R. Credland.
From the Librarian, Manchester Free Public Libraries.

Massachusetts Agricultural College. Twenty-sixth Annual Report.
From the College.

Massachusetts. Board of Commissioners of Savings Banks. Annual Report for 1888.

Massachusetts State Library. Report of the Librarian for 1888.
From the Library.

Mechanics' Institute of San Francisco. Report of the Twenty-third Exhibition.
From the Institute.

Meriden Scientific Association. Transactions. Vol. 3.
From the Association.

Meteorological Council. Royal Society. Hourly Readings. 1886. Part 1.
Weekly Weather Report. October 1st to December 31, 1888.
Report to the Royal Society for the year ending March, 1888. From the Council.

Montana. Reports of the Governor to the Secretary of the Interior for the years 1878, 1881, 1883, 1885, 1887 and 1888.

Third Annual Report of the Superintendent of Public Instruction for the year 1881. From the Governor of Montana.

National Electric Light Association. Bulletin No. 6. Sixth Series. From the W. J. Johnston Company.

New Jersey. Adjutant-General's Reports for 1861 to 1886, excepting for 1862, 1866, 1870, 1874 and 1880. From the Adjutant-General.

Newark, N. J. A History of the Old Burying Grounds as contained in the case of the Attorney-General against the City of Newark. 1888. From the Society.

New York State Agricultural Society. Transactions. Vol. 34. 1883–1886. From the Society.

North Carolina Agricultural Experiment Station. Bulletin No. 62. From the Station.

Ohio State Board of Agriculture. Annual Reports. 37th, 38th and 42d for 1882, 1883 and 1887. From the Board.

Ohio State Tramway Association. Proceedings. 1888. From the Association.

Ohio Valley Centennial Exhibition. Exhibit of the Navy Department. From Lieut. Richard Rush, Navy Representative.

Oldham, R. D. A Bibliography of Indian Geology. From the Director, Geological Survey of India.

Ordnance Department, U. S. A. Annual Report of the Chief. From the Chief.

Parrish, Joseph. Climate and Malaria. Medical Jurisprudence of Inebriety. From the Author.

Patent Office, U. S. Specifications and Drawings. February, 1888. From the Office.

Pennsylvania Canal Company. Eighth to Twenty-second Annual Reports. From Mr. Horace Whiteman, Secretary.

Pennsylvania Railroad Company. Forty-second Annual Report. From the Company.

Philadelphia and Erie Railroad Company. Thirty-eighth Annual Report. From the Company.

Philadelphia and Reading Railroad Company. Report for 1888. From the Company.

Philadelphia Social Science Association. Industrial Education in Europe. By L. W. Miller. From the Association.

Popular Science Monthly. July to November, 1885. From Spencer Fullerton.

Rogers, Henry R. Absolute Vacuum.

Ice-lens of 1608. From the Author.

St. Louis Public Library. Annual Report 1887–88. From the Librarian.

San Francisco Municipal Reports, 1880–81, 1883–84, 1885–86, 1886–87, 1887–88. From the Board of Supervisors.

Shinn, J. Improvement in the Manufacture of Heavy Guns and Shafts. From the Author.

Signal Office, U. S. Daily International Chart. December, 1887. Summary and Review of International Meteorological Observations. December, 1887. From the Office.

Stead, J. C. Useful Information Relative to the Economical Generation and Employment of Steam. From F. Leclere.

Storr's School Agricultural Experiment Station. Bulletin No. 3. From the Station.

Summit Branch Railroad Company and Lykens Valley Coal Company. Annual Report for 1887 and 1888. From the Companies.

Syracuse, N. Y. Report of Commissioners on Sources of Water Supply. From J. J. R. Croes, New York City.

Syracuse, N. Y. Report of Commissioners on Sources of Water Supply. From the City Clerk.

Taunton, Mass. First and Third Annual Reports of the Water Commissioners for 1876 and 1878. (2 copies each.) From the Commissioners.

Texas. Geological and Mineralogical Survey. First report of progress. E. T. Dumble, State Geologist. 1888. From the State Geologist.

Treasury Department, U. S. Comptroller of Currency. Annual Report. 1888. Vol. 2.
Annual Report of the Secretary for 1888. From the Department.

Virginia. Annual Report of the Commissioner of Fisheries. 1882. From the Commissioner.

Wisconsin Farmers' Institutes. 1888. Bulletin No. 2. From W. H. Morrisson, Superintendent.

Wisconsin State Board of Supervision. First to Third Biennial Reports. 1883–84 to 1887–88. From the Board.

Wyoming Territory. Reports of the Governor to the Secretary of the Interior. 1886, 1887 and 1888. From the Governor.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, March 20, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1889.

JOSEPH M. WILSON, President, in the Chair.

Present, 170 members and seventy visitors.

Additions to membership during the past month, sixty-seven.

The special committee to increase membership made a report of progress and was continued.

The special committee to prepare a memorial of the late WILLIAM PETTIT,

member of the INSTITUTE, presented a report, which was accepted and referred to the Committee on Publications.

Mr. WM. B. LE VAN presented a communication on the compound locomotive, giving historical account of the development of this improved form of engine, with especial reference to the English-built locomotive, "Dreadnaught," lately purchased by the Pennsylvania Railroad Company. Mr. LE VAN'S remarks were illustrated with the aid of the lantern. (Referred for publication.)

Capt. E. L. ZALINSKI, U.S.A., read a paper on the "Pneumatic Dynamite Gun," giving a history of the experiments that had been made and the results attained in the art of throwing projectiles charged with high explosives from guns, with the aid of compressed air. The paper was fully illustrated with the aid of lantern pictures and the exhibition of important parts of the electrical discharging appliances employed. The paper evoked considerable discussion and has been referred for publication.

The thanks of the meeting were unanimously tendered to Captain ZALINSKI at the close of his address.

The President named the following standing committees of the INSTITUTE for the current year, viz:

STANDING COMMITTEES OF THE FRANKLIN INSTITUTE FOR THE YEAR 1889.

Library.	*Minerals.*	*Models.*
Charles Bullock,	Clarence S. Bement,	Edward Brown,
J. Howard Gibson,	Persifor Frazer,	John H. Cooper,
Fred'k Graff,	F. A. Genth,	C. Chabot,
Geo. A. Koenig,	Edwin J. Houston,	L. L. Cheney,
S. H. Needles,	George A. Koenig,	N. H. Edgerton,
Isaac Norris, Jr.,	Otto Lüthy,	John Goehring,
Chas. E. Ronaldson,	E. F. Moody,	Morris L. Orum,
Wm. P. Tatham,	H. Pemberton, Jr.,	Chas. Richardson,
John C. Trautwine, Jr.,	Theo. D. Rand,	John J. Weaver,
Lewis S. Ware.	Wm. H. Wahl.	S. Lloyd Wiegand.

Arts and Manufactures.	*Meteorology.*	*Meetings.*
J. Sellers Bancroft,	Lorin Blodget,	Hugo Bilgram,
George Burnham,	Charles M. Cresson,	Geo. V. Cresson,
Cyrus Chambers, Jr.,	Edwin J. Houston,	G. M. Eldridge,
Franklin M. Harris,	Isaac Norris, Jr.,	Fred'k Graff,
Wm. B. Le Van,	Alex. E. Outerbridge, Jr.,	Henry R. Heyl,
C. C. Newton,	J. S. W. Phillips,	Washington Jones,
Henry Pemberton,	M. B. Snyder,	G. H. Perkins,
Alex. Scott,	Wm. P. Tatham,	Sam'l R. Marshall,
Thomas Shaw,	H. Wiley Thomas,	Chas. E. Ronaldson,
Wm. Vollmer.	Wm. H. Wahl.	Wm. H. Thorne.

Adjourned.

WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVII. MAY, 1889. No. 5.

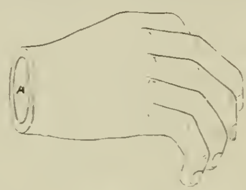
ON MARKS' ARTIFICIAL LIMBS.

[*Abstract of the Report of the Committee on Science and the Arts, presented at the Stated Meeting of the* INSTITUTE, *held Wednesday, January 16, 1889.*]

This subject was submitted to the Committee on Science and the Arts for examination, and upon the reading of the report and exhibiting the specimens and illustrations, appeared to be of sufficient interest to warrant the attention of the INSTITUTE at this meeting, and a concise abstract of the report was accordingly prepared. This abstract follows and describes the invention in its several stages of progress.

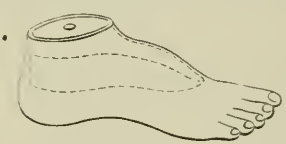
The first improvement consisted in the substitution of an elastic artificial foot, made of india-rubber, without any joints whatever, for the artificial foot, previously made of wood, with joints to permit motion of the ankle and toes, and also an artificial hand made of india-rubber, simulating the missing member. As a matter of course, such an artificial hand, which is here illustrated, could do little else than

restore appearances; it had, beside this, the merit of not wearing out gloves and other apparel as rapidly as its wooden and metallic articulated predecessors, and it was much less costly and not so unpleasant, when it came into personal contact. The rubber foot, which is also here illustrated, consisted of a wooden block rigidly secured or formed with the leg and extending downwardly to within about two-fifths of the distance from the ankle to the sole, and forward to nearly the first articulation of the meta-



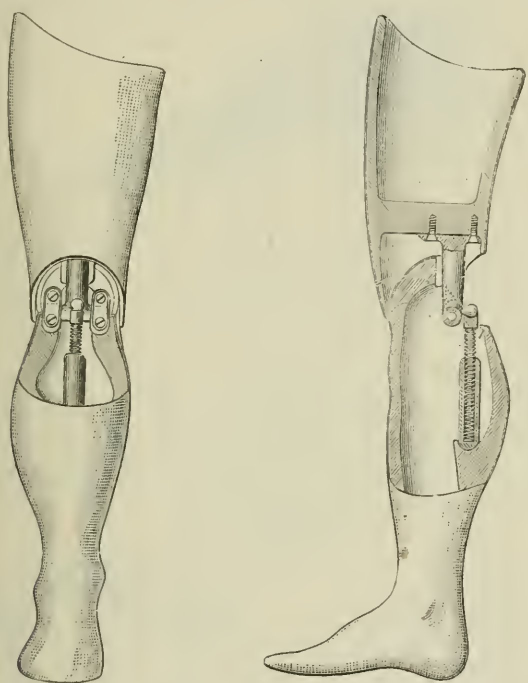
tarsus and toes; this block was covered with india-rubber, and all the rest of the foot, from heel to toes, was formed of elastic vulcanized rubber.

The action of such an artificial foot was that of an elastic segment of a wheel. The shock of placing the weight upon the heel at each step was avoided by the elastic cushion of rubber forming the heel, and as the weight was progressively transmitted to the forward part of the foot, by the combined effect of muscular exertion in the remaining part of



the natural limb to which it was applied, and the momentum previously acquired, an easy flexure of the toes took place, which, reacting elastically as the weight was transferred to the other limb, assisted in the flexure of the knee joint, giving an easy and naturally appearing movement. Such artificial feet were, upon trial by those who were maimed and had used other artificial substitutes, found to be easier to use, lighter and more comfortable. They were rapidly introduced into use, and have proved from their greater simplicity more durable and far less destructive to clothing.

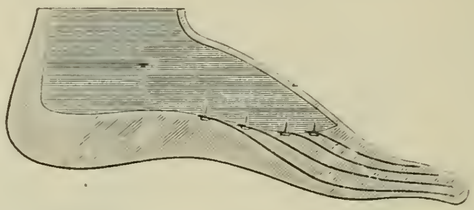
The next improvement (the picture of which is here shown) is an improved and simplified construction of the knee joint of artificial limbs, made with a view to strength, facility of accurate manufacture and easy application. This joint consists of a flanged plate, secured by screws to the under surface of the thigh socket, and has formed, integrally with it, of steel, by drop forging, a cylindrical pillar, terminating in two lateral journals having the same axis, resembling an inverted capital letter T.



These journals perform the function of the condyles of the femur, in the natural limb, and are fitted accurately in bearings formed with oblique caps, secured by screws in the rear of the knee portion of the leg.

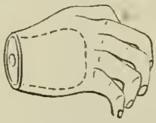
On the rear of the pillar, in about the same horizontal plane as the axis of the journal when the limb is extended and erect, is formed a short lever, having a spherical end, against which a cup, formed upon the upper end of a

sliding plunger, is pressed upwardly by a spring in a guiding cylindrical case, having a hemispherical lower end resting in a correspondingly shaped cup or cavity in a shoulder in the interior of the calf portion of the leg. When the limb is extended, the spring operates with full effect, in holding the limb extended; as it is flexed the lever gradually assumes a greater angle to the line of reaction of the spring and cup, so that, when it is flexed with the thigh at right angles with the leg, the



spring has no motion or effect, and if flexed still further, the spring then operates to assist in further flexure. The pillar and journals are made hollow, so as to reduce their weight.

It is obvious to every mechanic from the form of these parts, that they can readily and accurately be finished by drilling and turning, that from their shape they must possess great strength, and that they can easily be fitted accurately into their working positions in the limbs.



Another useful feature of this form of joint is, that the upper part of the pillar forms an effective stop, to arrest the forward motion of the thigh upon the leg during extension, by coming in contact with a cushioned cavity in the rear of the knee; this point of support being at a considerable distance from the axis of the knee joint, avoids any severe strain and shock from the sudden extension of the limb, which in other constructions, having the stops made in plates at the sides of the joint, are necessarily close

to the axis of motion, and consequently are subjected to a greatly increased strain.

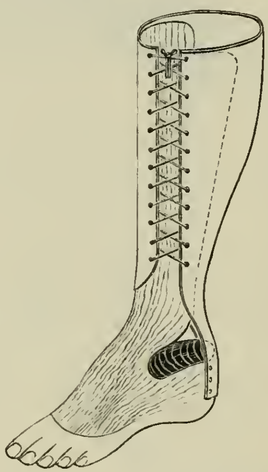
This concussion of the stop is found to be a frequent cause of breaking, both of the stops and joints of other forms of limbs, and has had a great deal of ingenuity expended upon it to avoid it, by providing check straps or cords, reaching from the thigh to the leg, and designed to stretch tight before contact of the stops occurs. These cords required greater care to keep adjusted to the proper tension than could readily be given to them. The simple contrivance, here shown, obviates the entire difficulty.

The axis of the knee joint is placed near the back of the limb, so that the weight of the wearer ensures a firm support on the limb when extended, and at the same time slight exertion suffices to move the limb in stepping forward.

The shell or parts, which in form imitate the natural limb, are made of light willow or basswood, as thin as is consistent with strength in the lower part, and in the upper part excavated to fit the remaining portion of the natural limb; these are covered tightly with parchment and painted and varnished to resemble the complexion of the natural skin.

The continued use of the limbs thus constructed demonstrated that the front portion of the foot was too easily flexible, or rather that greater elastic force was desirable, and this requirement was met by the inventor by a device in which a textile fabric was introduced between the lamina of india-rubber forming the ball and toe portion of the foot, as here shown in the drawing.

The desire to adapt the india-rubber hands to changes of flexure, for purposes of better and more natural appearance and to grasp light objects, led Mr. Marks to improve them by making a light wooden core in the palm or metacarpal portion of the hand and inserting ductile or flexible metallic



wires in such core, which extended centrally through the fingers. By bending the fingers they retain the form in which they are set. The test of several years' use of these last-named improvements has proved their utility.

The latest improvement in artificial limbs consists in forming the leg and foot part of a single piece of wood, having the grain curved naturally in its growth, such pieces being procured from the parts of the trunk contiguous to the roots and branches of trees; limbs made in this way are stronger with the same amount of wood remaining in them, than when made of parts and glued together, and are made water-proof, which is a specially valuable feature

when the occupation of the wearer exposes it to constant dampness, or to water itself, as in fishing, mining, dredging, etc.

By making limbs in this manner from natural curves in the growth of the wood, it has become practicable to make light and substantial artificial feet, adapted to partial amputations of the foot. Such appliances are shown herewith, and have been used with unprecedented satisfaction where articulated feet were clearly impossibilities.

The advantages derived from lightness of such artificial substitutes, will readily be apparent, when the resistance to motion from inertia is considered. The ankle and foot and

lower part of the limb being light and hollow, move easily and promptly with but little exertion from the remaining part of the natural limb, and the comfort and ease of the wearer are thereby greatly promoted.

With the specimens of limbs are submitted well-perfected adjuncts in the way of suspender straps and girdles, and great ingenuity and skill have been displayed by these inventors, in adapting limbs to specific cases which, whilst useful and light and highly commendable, cannot be particularized in this report.

The Franklin Institute has not made any examination in this department of the arts since January 11, 1849, when,

as appears on page 61, Vol. xlix, of the JOURNAL, they reported upon the merits of the Palmer artificial limbs. Since this time about sixty or more patents have been granted for alleged improvements in artificial limbs, nearly all of which, except these, which are the subject of this report, added complications or additional parts to the limbs. In none of these inventions does there appear such desirable simplicity of construction and reduction of cost of production as in those under consideration. The makers are enabled to make most durable and substantial workmanship of all parts, and have demonstrated all of these points by making something over 9,000, which are in constant and satisfactory use.

The extreme simplicity of construction has proved the means of bringing their cost within the reach of many persons requiring such appliances, who could not otherwise afford to use and maintain them, and there are now many persons using them and actively competing with others in many lines of industry: among them, machinists, blacksmiths, farmers, fishermen, carpenters, moulders, instrument makers, railway conductors, engineers, and, in fact, representatives of nearly every handicraft.

Mr. Thomas Kehr, a skilled workman in all branches of their manufacture, who works daily at the bench, standing upon two of them, demonstrated publicly at the INSTITUTE meeting their facility of use and value in walking, better than anything that can be said upon the subject. (One of Mr. Kehr's legs was amputated in the middle of the femur and the other an inch and one-half below the patella.)

[The report of which the foregoing is an extract, and which embraced the recommendation of the award of the John Scott Legacy Premium and Medal, was signed by S. Lloyd Wiegand (*Chm.*), L. L. Cheney and N. H. Edgerton, and approved and adopted by the Committee on Science and the Arts, at its stated meeting, held Wednesday, February 6, 1889.]

AMATEUR PHOTOGRAPHY IN ITS EDUCATIONAL RELATIONS.

BY PROF. CHARLES F. HIMES.

[*A lecture delivered before the* FRANKLIN INSTITUTE, *February 11, 1889.*]

The Lecturer was introduced by the Secretary of the INSTITUTE, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

The subject as announced for the lecture this evening is Amateur Photography. Now, whilst many photographic societies experience great difficulty in defining satisfactorily the term Amateur Photographer, I apprehend that we will have little difficulty in agreeing in regard to the term Amateur Photography, and I desire at the outset that there may be no misunderstanding about it. The first mentioned difficulty originates in the two-fold character, possessed by many who practice photography. They have an amateur and a professional side, and frequently in the professional the amateur side is so unduly developed that the professional is almost lost sight of, whilst, on the other hand, in some amateurs the development of professional traits is only restrained by the quality of their work. By amateur photography then this evening we mean amateur practice, whether by professional or non-professional.

In determining upon the treatment of the subject I have been influenced by a knowledge of the fact that this INSTITUTE is deeply interested in the encouragement of popular scientific education, and healthy public sentiment upon this point, as well as in higher scientific investigation. A few years ago, in the course of lectures at the International Electrical Exhibition, under your auspices, I had the pleasure, in a lecture on Actinism, to illustrate the scientific basis of photographic practice, and to call attention to some of the most recent advances, of which orthochromatic photography was

then, perhaps, the most recent, for the further development of which this INSTITUTE has done so much through the contributions of Mr. Ives. This evening I propose to call attention to and emphasize as best I can some of the more purely educational features of photographic practice, the resources of which in this respect have more particularly impressed me in connection with instruction for many years of classes in a course of so-called liberal education, I mean an ordinary college course, as distinguished from a technical course. I cannot but recognize, too, as a fact that amateur photography has perhaps reached its highest development in this city, and that its societies here are not only of the oldest, but among the most active and progressive, and that consequently it would hardly repay to consume time in demonstrating well-known processes. Any purely practical suggestions therefore, as to formulæ, wrinkles and dodges, will be purely incidental.

Amateur photography is sometimes called, and perhaps oftener looked upon, as a popular craze, as the fashionable amusement or pastime, as something that will have its day and in turn be supplanted in popular favor. The advertising columns of periodicals of current literature would tend to confirm such an impression. This treatment of amateur photography as a popular craze has a tendency to depress its practice to a lower level, and to check temporarily its inevitable permanent growth. But a closer consideration of this pastime, of its nature, its relation to permanent desiderata—not of a strictly commercial or technical character—will discover elements of permanence that distinguish it from the thousand and one other ephemeral minor arts that appear upon the surface of society for awhile and then lapse into merited or unmerited desuetude. As one who has employed photography, not only for recreation and entertainment, but for the higher uses of which it is susceptible, for research and as an educational means, I feel that in this place it will be proper and perhaps profitable so to discuss the subject that all who claim a high ideal for the art science may be strengthened in their advocacy and practice.

Now, nothing perhaps will show more clearly the permanent character of amateur photography than a brief glance at its history among us. There is something in it that stamps it as essentially different from the other arts alluded to. As an amateur of thirty years' experience, as a constant reader of its literature, as one enjoying each advance, each new application, and the rapid growth of photography as an amateur art, I see no backward step, no halt, no diminution of numbers or of devotion, but a steady forward movement along all lines, sometimes rapid, at other times slow, but always an advance. But the amateur of thirty years ago required many virtues in a high degree now scarcely known. At this point I miss much the inspiration as well as the moral support of the expected presence of your honored president, unavoidably absent to-night, to whom I could appeal to substantiate much that I may say. To him I owe my trend, or inspiration, if you please, in this direction. He had experimented with a process nearly related to one that to-day produces perhaps more square yards or miles of photographic prints, than all others together. I well remember the pleasure and surprise occasioned by the exhibition of a few of his early blue prints of ferns, accompanied by the statement that they were photographs, and after the statement of the simple process by which they were produced I was fixed as an amateur photographer. Everything at all available was soon printed in blue—leaves, ferns, laces, MSS., even old ambrotypes, scraped clean of their black varnish. The process, I said, was nearly related to the present blue process, but, like all other processes of that day, it was slow, exceedingly slow by comparison. The preparation of the paper consisted in simply brushing over it, lightly, back and forth, with a tuft of cotton, a solution of ferricyanide of potassium of a strength of about 100 grains to the ounce of water, the paper being pinned to a board at the corners. That paper can be exposed for hours, or even days, without danger of overprinting. It was so slow that many lost faith in it. After I had published the formula, more than twenty years ago, in *Leaf-Prints or Photography without a Camera*, with a

recommendation of it to beginners on account of its simplicity, I received many inquiries and complaints from all directions, and among them one through the publishers from Constant Guillou, whom all older amateurs will remember, and whom I remember well by his exquisite Cuban views received from him as a member of the first Amateur Photographic Exchange Club. His opinion in regard to the process was very pronounced, whether he named it a mistake or a fraud, I do not recollect. I can only account for the roundabout way in which his opinion reached me, by a failure on his part to recognize on the title page the name of one of his photographic correspondents. There was one effective answer to all these communications —a print produced by the process, and advice to give them time enough. The process is not without its good points. Some of the failures with it were due to want of discrimination on the part of the druggist, to whom early amateurs were most likely to go, between ferricyanide and ferrocyanide of potassium.

But it was not in the nature of things that one should remain contentedly simply a photographic printer, if there was even a remote possibility that images in the camera could be produced. To be sure, photographic cameras were not temptingly displayed much in the windows or pictured in advertisements. They were at best rather crude and decidedly expensive. But here again, my friend, your president, moved a little in advance. He made his camera, furnished with a spectacle lens. It was primitive enough, but it had one great virtue—it was at least light-tight. As to the negative process employed, it was one that I would hesitate to attack to-day with certainty of success. It was dry, of course, and was called Whipple's Albumen Process, a French process, improved by the addition of honey or syrup to the albumen, the vehicle of the alkaline bromide converted into sensitive silver bromide in the nitrate of silver bath. After sensitizing, the plates were washed and dried. Many things were learned, not strictly photographic. We learned to break eggs with a smart tap, so as not to affect the yelks, to hook out the germs with a toothpick, beat them to a perfect

froth without a patent egg-beater. We studied well the interminable list of "don'ts" and "take cares," acquired a proper dread of dust, which we were told was the greatest enemy of successful photography. We followed the book in all its multitudinous and minute details, in the cleaning of the plates, the levelling, the coating, the washing, the drying, and the storing of the finished plates—for we were groping around in an unknown field in helpless and almost hopeless darkness, and we held on to the leading-strings. But the book by Geo. W. Coale, though quite small and unpretentious, was a full one, carefully prepared, embodying much experience. There was not much left to be read between the lines. I cannot now ascribe a single failure to misdirection or want of direction. Of course, there was always room enough for thought on our part, but the whole character of the book is in marked contrast with the most of the photographic literature placed in the hands of the tyro of to-day with his outfit. To be sure, such a book was more necessary then than now. The discouraged tyro to-day can drop in on his older brother, entertain him with his little troubles, and receive advice and comfort; or, if they are too big for that, he can take them to the society at its next meeting. We had a society, with an excellent constitution, elaborately engrossed, and its initials, "P. P. S.," are on many unique prints, but it was not of much help to us, as we were the only members, and the constitution never could be put fully into effect for want of members to fill the offices. There were a few other amateurs, but we never discovered them, nor they us.

But to return to the Whipple process; when everything was ready, the book said, "to prepare six good plates is an hour's work," and that they would "be good for at least one month if kept absolutely free from light, moisture or deleterious atmosphere," under the latter cautioning against the neighborhood of fresh paint, varnish or ammonia. It closed that chapter with the caution that the amateur should not be "disheartened by repeated failures to get good plates," "that the difficulties were only to be overcome by sheer perseverance, with the exercise of patience and judgment," and the comforting assurance that "when success was attained

the exercise of the skill required would impart to it an attraction which the more mechanical and *infallible* methods lack," and the "infallible" was emphasized by the author. What an inspiration to patient, painstaking, thoughtful work to a boy of brains and character; what an encouragement to perseverance under difficulties! What an educational influence in this, compared with the inducements held out for the practice of photography and too much of its literature of to-day! It says, too often, "You need not know anything about anything; you need not use your brains—in fact, you needn't have any; as to skill, in fact, there is not as much needed at any stage as to turn a barrel-organ, and withal very little outlay; it is only necessary to touch a spring, or turn a crank, and the whole pictorial world is yours." After the Whipple process plates were prepared, how precious they were! They represented a great deal—not, perhaps, of money, but of what was more than money—and you may infer that the views for them were selected and studied with great care. There was not much firing at random with these plates. A little incident will illustrate their slowness. On one occasion, standing with head uncovered, the hat being used to shield the lens, we had twenty minutes to employ in speculating upon the future of photography, and fixed the ideal, unattainable limits of sensitiveness as that which would permit the simple uncovering and covering of the lens, rather leisurely at that, and yet have the picture fully impressed. We never reached the snap-shutter stage, even in imagination. But what a state of mental tension, of suppressed expectation, the development of those plates involved, as the solution—not solution "A," nor solution "B," nor a mixture of them, nor somebody's infallible ready-mixed developer—was poured over them, not in the tray of the outfit, but in the home-made tray. That developer was carefully compounded, every ingredient carefully weighed, or measured, and recognized and remembered as a friendly factor in the case. Then the injunction was to watch the plate attentively during development, to inspect its progress from minute to minute, just as with your modern plates; exactly why, how-

ever, never was very apparent, as half an hour's soaking, with all the watching, never over-developed them ; but if in that time it did reveal the unmistakable outlines of a white-washed fence, or a barn, it afforded the gratification of the confirmation of our faith in the process, a realization of the fact that a spectacle-lens image could impress itself even on our plates. Although I never reached with this process that happy stage incident to a clean, well-developed negative, which our author told us was in itself a beautiful object, still the negatives, such as they were, were regarded with an affection that was not lessened by the unappreciative criticisms of our friends, who might say: "Yes, there is the fence, there is the barn, but why does it look like the deluge or midnight?" But there was more than photographic success in all this; there was that discipline that led us to venture on the apparently more mysterious and seemingly more difficult collodion process. The results of the first attempt with it were so quick, so satisfactory, so certain, by comparison, that its trial at once marked a new departure, from the dry to the wet process, which created new necessities. It required a portable laboratory, portable tent, portable silver bath, trays, bottles, etc., etc., and ingenuity was taxed to its utmost to minimize the impedimenta and to store them so as to reduce the time required for setting up and striking the tent.

This tent is only exhibited to emphasize that period of landscape photography, entirely with the past, when humidus had the field to himself. Besides the cumbersomeness of the apparatus, there were the most vexatious annoyances, caused by the photographic reagents, and especially by the unreliability of the sensitizing bath, upon which the responsibility for most of the troubles was placed, and perhaps justly at mid-summer temperatures. The literature of the nitrate of silver bath, read with avidity by amateurs of the past, would itself fill volumes in which the dry-plate amateur has comparatively little interest. The spectacular feature of the tent was not without its annoyance. A bag of yellow and black muslin, enclosing the head and body, with the lower extremities still well dis-

played below, was calculated to excite unappreciated comment, and always occasioned an unpleasant realization to the one within that the small boy might be tempted to do more. There was a dry process, however, that soon sprang up that disputed the field, and one that, although not suited to compete with the gelatine plates in rapidity, has many points to recommend it, especially for stereoscopic transparencies, as it is simple, certain and beautiful in its results and inexpensive, and would almost justify the amateur in adding the collodion bottle and silver bath to his outfit. I allude to the Tannin Process. The well-cleaned plates are coated with any good commercial bromo-iodized collodion, sensitized for five minutes in a nitrate of silver bath of forty-five grains to the ounce of water, saturated, of course, with iodide of silver, then *thoroughly* washed in water, then flowed with a filtered solution of tannin of fifteen grains to the ounce of water, and then dried. The washing is the most troublesome part of the process. It can be reduced by washing the plate in several changes of water, and then flowing it with a five per cent. solution of iodide of potassium, and then rinsing. My own practice, published a few years ago, was to prepare the plates up to this stage* in the broad daylight, and allow them to dry, as iodide of silver formed in presence of iodide of potassium is insensitive, and that formed in the film in the nitrate bath is rendered insensitive by the flowing with iodide of potassium. These plates can be sensitized at any time by immersion in or flowing with a solution of tannin. The development with pyrogallic acid, and nitrate of silver, restrained by citric acid, is simple and controllable, and the light permitted comfortable, whilst the finished negatives, or transparencies, have a rich brown tone, leaving nothing to be desired. The plates will remain sensitive for, at least, two years.

Now this retrospect as a scrap of history has little value, but the points touched on will emphasize the characteristics of early amateur photography. Those were its heroic days

* *American Jour. Sci.*, July, 1874.

There was much hard work, and there were few tangible results. If we worked for pictures, we were poorly repaid in numbers or quality, but we worked rather for light, for improvement of processes, for the detection of the subtle conditions of our oft recurring failures, and we had to find our highest reward in that exquisite pleasure of success wrung from unfriendly conditions. If our pictures were not good in every respect, we felt that we had done all to merit that highest excellence of any scientific work, the highest excellence attainable by the processes and apparatus at our command. And as we look back over those years, and note now how many have continued, or have resumed at intervals, the practice, as well as the fresh additions of thought ful, careful, enthusiastic amateurs, can we not infer that thirty years after this the camera will still be even more the *vade mecum* of many, in years of greater leisure, and that amateur photography is not simply a popular craze? The efforts of the trade to push the practice of amateur photography by any mode of presentation that may be most effective, and in any place that may be open, even by representations that are almost sure to disappoint, or that may seem to belittle the practice, may be perfectly legitimate from a business point of view, and in the end may do no harm. The boy who is inveigled into buying a Kodak, or who has a father, or a friend, that would make him so suggestive a Christmas gift, may soon find that there is something beyond the Kodak, and develop into a high-class amateur. If there are others with whom the seed may fall in shallow soil, and whose Kodaks may soon find their way to their several garrets, or to the second-hand store, this circumstance can hardly be considered an argument against the Kodak. But in this Augustan age of photography, with its perfected technique, with plates and processes and apparatus that leave scarcely any quality to be desired, for any purpose, at the command of all, is there nothing left to require and develop the highest qualities in its devotee? Certainly there is as much in it as at any time. The ground has simply changed. There are broader applications to be made, there are more subtle conditions to be

considered, there are higher excellences than those of merely technical success, there are demands for work of higher merit than that embodied in mere sharpness of definition or gradation in development. The high lights may have been allowed to take care of themselves, and the details in the shadows may have been taken care of in the development, as is so often suggested, but the result may be all the more a discredit, because of the absence of thought, of taste, or of judgment, which it discloses, and which the perfected technique, and easy methods render unpardonable as well as conspicuous. As some one has said, advances in photography have made it easy for any one to take poor pictures, but the same standard of excellence remains to-day as thirty years ago, the highest work in all respects attainable. Success does not consist in the number of shots that can be made on an excursion, but in what there is in the results to give them any value. The cheapness of plates and the ease of exposures are not promotive of the highest class of practice. A restraint should be put upon the enthusiastic sort of drag-net tendency to take everything, and trust that something will prove desirable.

But, unquestionably, the great and most natural desideratum with most who enter upon amateur practice is the rapid acquisition of that technical knowledge and skill that may render possible satisfactory results. They may be willing to put all the thought, and care, and trouble into it, but they do desire tangible returns. In a large city, and a city in which amateur photography has, perhaps, reached its highest development, few can fully realize the discouragement under which the more rural amateur works, who can only eke out his experience from the journals. A few years ago the thought occurred to me that a summer school of amateur photography, at some quiet place of resort, might meet a felt want of some. It was discussed, perhaps somewhat enthusiastically, in the hearing of a gentleman, who pigeon-holed it away, and, after a few months, I received a pressing request to organize and conduct such a school for two weeks, with conditions annexed that seemed to render success possible. I elabo-

rated a plan with considerable care, and prepared for its execution on a generous scale, and acquired considerable experience that may be of value to anyone attempting a similar enterprise. The resort was a new one, on the top of the Alleghenies, a hundred cottages and a few small hotels held the whole population. I had never seen the place, but I shipped in advance a whole car-load of apparatus, comprising a full assortment of cameras and everything that would illustrate photographic practice, and, in addition, permit half dozen popular lectures on cognate subjects. The school was well advertised, the terms were very moderate. I reached the place a few days before, only to find that not a student had been enrolled, and that no preparations had been made for it. The school of photography could not be found with a microscope. The officers of the settlement, apparently regarding the enterprise as a failure, were not to be found; not a ticket had been disposed of for the course of popular lectures, upon which they had placed their main reliance. All the same, the carload of twenty-two boxes was taken to an unoccupied storeroom, that leaked light at many crevices, but which was roomy, and the shelves and counters of which promised to be useful. Withal, there seemed to be but one chance remaining for a semblance even of success, and that lay in the possibility of presenting the practice of photography in such a way that some might consider it favorably, at least in its simpler applications. Finding the man in charge of the grounds, I advised him to have some dodgers struck off and distributed, inviting to a free lecture on photography, the evening before the appointed opening of the school. There were many ludicrous incidents connected with the whole affair up to this point, and not the least these dodgers, in their composition and mechanical execution. But perhaps 200 auditors were on hand, about the whole available population of the place. Discarding all thought of a popular scientific introductory, I began with photography, presented the leading features of its practice, dwelt upon the simpler processes in detail, exhibited a lot of blue prints, gave an opportunity to parties desiring

further information to ask questions, and invited any desiring to enter to present themselves next morning at the room. And the school was a remarkable success. Twenty-five presented themselves on time, and the number soon increased to thirty, when no further encouragement was given to enter, and unless I had been fortunate in having with me one of those unduly developed amateur professionals I would have been unable to organize and carry on the school in the absence of many of the conveniences that we are apt to consider indispensable until we are obliged to do without them. But in that excellent mountain atmosphere, often up at six in the morning, and as often not in bed before twelve at night, we ran that school for two weeks, or, rather, it ran us.

There was enthusiastic, earnest, thoughtful, continuous work, acquiescence in inevitable inconveniences and discomforts, and gratifying progress. The ages ranged from over sixty to a dozen years, all equally enthusiastic. It was not a craze. The apparatus provided for illustration and display, as far as applicable to amateur wants, was laid hold of. Fifteen complete outfits were disposed of, and others subsequently ordered, and occasionally yet a package of prints reaches me, which tells of continued interest in the practice. If you were to ask me, to what I attribute the success, under the unpromising conditions, I would answer, to the plan of the school; and there may be in it a hint for dealers, as well as for any who might wish to conduct a similar enterprise. The exercises were arranged on a progressive plan. There were four distinct courses from which to select, but as each higher course included the privilege of the lower courses, all were put upon the first course, whatever their selection. In other words, something was given the students to do, at the start, that they could reasonably be expected to do. They were tempted only to undertake what was practically certain of success, what was entirely within their range, and then they were allowed to do it, thinking and all, with the least amount of direction and supervision consistent with the proper use of their time. In other words, they were not overinstructed. Now,

there is nothing like success, and especially independent success, to whet the appetite for more and higher practice, as well as to inspire that measure, and kind of confidence so necessary in many cases. Blue printing, the first course, was therefore given a prominent place in the announcement. Most effort was expended in displaying fully its applications and possibilities. Prints of every variety were conspicuously exhibited, from large architectural plans to the humblest leaf prints. Cards, with prints from negatives, of a great variety of subjects, including series of scientific subjects, copies of engravings, landscapes, etc., were hung up, not only for inspection, but to facilitate the selection of negatives for practice by the students. No one can fully realize the attractiveness of this simplest of all photographic processes and the resources it furnishes for photographic instruction, until he has seen it properly presented to an assemblage of two dozen individuals of average intelligence, affected with the ennui of the average summer resort. It can be made introductory to all the elementary principles of photography, to the characteristics of negatives, to printing manipulations and to the acquisition of that photographic sense upon which subsequent processes may be based. The majority enrolled for this course, most without the remotest intention of going further, but after the use of negatives the desire to produce them was most natural, and the second course of wet-plate camera practice was soon entered upon with even more enthusiasm by most of them. I had anticipated a run upon this most fascinating of all photographic processes to the beginner, and was prepared with a supply of negative baths and wet-plate cameras. Silver printing was touched upon lightly. Platinum printing was regarded with more favor, as it is the process for the amateur, next, perhaps, to bromide paper, which at that time was not in the market.

After these courses, dry-plate photography almost took care of itself. All instruction in the use of the camera, focussing, selection of view, etc., had been already given, and that without the inevitable waste of time by the tyro with a dry-plate outfit running around to hunt up something

to take, and which he seldom gets, because he does not know a good negative when he sees it. A school of photography must rest upon a correct pedagogic basis, or it may be so only in name, and fail to accomplish what can be done by it. So, too, in the skilfully prepared advertisements of dry-plate outfits, accompanied by pictures of cameras pointed at running dogs or jumping horses, there is great risk of such disappointment of legitimate expectations, and consequent discouragement, that the camera it sells may soon go to the garret. Parties frequently select their subjects in advance of purchase, and even promise pictures to all their friends, and it is not a small matter, as anyone knows who has experienced it, to explain the delay in delivery long after the camera has put in an appearance. I have in my pocket a letter just received from a bright little girl, asking advice in regard to an outfit suitable to take her little brother. I have no doubt she will succeed eventually, but I see between the purchase of the camera and the realization of her wish discouraging disappointments, which a girl of twelve may not survive photographically. I have written her frankly that it is not the camera that takes the picture, but the little girl behind it, and preparing her somewhat for her first disappointments, and assuring her that if she makes up her mind not to be discouraged, she will be able to get a picture of her little brother long before he becomes a man, which she may, after all, be inclined to doubt. The point at which photography is attacked has indeed much to do with the results, and the encouragement generally is to begin as far from the beginning as possible. If dealers were to put upon the market, with some display, complete outfits for blue printing, including the preparation of the paper, with suggestions of variety of work to be done, and include series of half dozen or more carefully selected negatives for practice, I am inclined to think the sale of negative outfits would be promoted, and a broader basis for persistent amateur practice be encouraged. Now, a word as to the literature of the school. In the earlier stages it consisted of brief, carefully prepared instructions upon the exercise in hand, first given orally, perhaps with

comment, and then posted in the room for reference, all supplemented by lecturettes of twenty minutes at the opening each morning, upon such topics as the practice for the day and the experience of the previous day suggested. Their own experience rapidly put flesh on these outlines, and especially with the encouragement in the use of the ever-present note-book and always-pointed pencil, which always accompany systematic and thoughtful work. At the close of the school they were not only prepared to use a photographic hand-book, but it had become a felt want. But I leave this subject of schools of amateur photography with the simple expression of the opinion, founded on facts continually forcing themselves on my attention, that there is a place for such schools; that there may not be much money in them, but that they would at least repay financially, and would furnish much pleasure to all parties.

But there is a more purely educational phase of this subject. Not many years ago text-book cram was considered a quite satisfactory method of instruction in science and if to it were added lectures with illustrative experiments, nothing more seemed necessary or possible. In recent years work by the student is recognized as having a value of its own, not only for the acquisition of fruitful knowledge, but of still more fruitful mental discipline, which latter many still contend is the chief end of a liberal education. Whilst it is not necessary to concede that that knowledge which may be useless is best adapted to mental discipline, it can with propriety be claimed that photographic practice, as part of a liberal education, must be judged by the same rule that applies to the other branches; that even if the camera be laid aside, never to be employed again, the discipline involved in practice with it would remain just as truly as that incident to the study of algebra or of trigonometry to say nothing of the calculus, never employed in after life, or of Latin and Greek, never read or spoken, or even of that practice of music, often so faithfully carried out in early life, only to be entirely laid aside later on. Now, in the early introduction of laboratory practice by the student, it seemed, in the nature of the case,

restricted to chemical work, and always attended with liability to run into mechanical methods, by reason of the general uniformity of the processes, as well as the similarity of the phenomena. Physical phenomena more varied in character, involving broader generalizations, and more numerous laws, capable of mathematical expression, and of ready verification were excluded by reason of the demand they seemed to make for apparatus, space, and time, and an apparent necessity for high mathematical attainments as a basis of their study. Now, recognizing the principle of the best attainable results with the apparatus employed, and realizing that it is not the extent of mathematical acquisitions, but rather the ability to apply that is called into requisition, and that the educational value of a physical laboratory may lie far below the line of the calculus, arithmetic, and elementary algebra, trigonometry and analytical geometry have new value and interest imparted to them. Photography presents many features that led me to adopt it as a laboratory exercise many years ago, and to retain it at present in the physical laboratory as a valuable educational means. It is recommended by the wide range and varied character of its operations, from the simple blue print to the highest scientific applications, as well as by the progressive character that may be given to its exercises. In common with many other minor arts, its results are things, not simply facts. They can speak for themselves, and are in the main permanent, can be referred to at any time, and are comparable with subsequent results. Attention can be called by the instructor to their different qualities at different times. It also recommends itself by the severe test it affords at every stage of patience, thoughtfulness, many-sided attention to minute details, promptness in judgment and promptness of response in manipulation, as well as of skill. The work of the tyro, to the experienced instructor; bears the easily recognized earmarks of neglect, or thoughtlessness, or ignorance, or want of skill at any stage. The learner soon discovers that nature recognizes no conditions as minor or trifling in photography.

It may be objected by some that photography is largely qualitative, but it might be reasonable to inquire, whether physical laboratory practice is not made to consist too exclusively of precise measurements. Work may require skill, closeness and precision of observation, and all the qualities developed in the highest degree by quantitative work, and yet not consist in fundamental measurements of lengths, and angles, and weights, and time. It may not seem to those, who merely read the advertisements, that photographic practice requires, and encourages careful, thoughtful, precise work and skill. But nothing is more deceptive.. A few years ago a section of students starting in upon photography appointed a historian. He had a voluminous account, but much of what they had learned was condensed in the motto of the title page: "It looks easy—try it." Indeed, very little practice renders it a wonder that any perfect negative should run the gauntlet of all the possibilities of failure. The demands upon the average man, too, are rather qualitative than quantitative, for quickness in estimating when the measuring stick cannot be applied. The expert samples wheat without measuring the size of the grains to a fraction of a millimetre, or weighing, though both size and weight enter into his estimate. In same way the quality of fabrics, as well as wool, cotton, is estimated. Even the physician in his diagnosis is qualitative beyond the thermometer. With the expert photographer this unconscious judgment that decides a negative to be first-class, before he begins to tell you why, seems almost a matter of feeling. Quality in these cases is the sum of many conditions, and as far as they are quantitative, rapidly estimated, not measured. In an educational photographic course there is, however, some choice of processes. Much that I have said in regard to blue prints may apply here, but for varied and peculiar excellences in this respect, perhaps no process can be compared with the wet collodion process. If it did not exist, it would be advisable to invent it for instruction. It allows the use of comfortable and abundant light, something not to be overestimated in the early practice of photography. The picture lies upon

the surface and manifests its qualities rapidly. More processes come under the observation and control of the student, and yet it is more rapid, in that completed results are reached more quickly than with the dry plates. Many experiments thus can be made in a comparatively short time. It is inexpensive, so that there can be no restraint on investigation by any thought of expense. But, perhaps, its chief value lies in the concentration in the briefest interval of time, of all the operations mental and physical that contribute to a perfect result—manipulation, observation, judgment. As you pour the developer upon the exposed plate every fraction of a second may be critical, especially with some kinds of work, as lantern slides. Not only close, quick observation, but prompt decision as to the quality of the picture, and equally prompt response of the hand to the judgment formed, involving skill, are all required. There lie between the perfect result and the barely passable one very few seconds in development. I sometimes feel as if no photographic experience can be complete without familiarity with some such process as this.

We have spoken of failures by the tyro, but among them are many the tendency to which he will never outgrow, and which should therefore cause no discouragement. Anyone is liable to get two pictures on one plate. No registering device will insure against it. Even in giving a student instruction upon this point the first puzzling indications, on one of the plates under development, rapidly grew into two dogs in two wagons in inverted positions, the unexpected interest in the picture somehow confusing the record of exposures. An experienced amateur, a D. D., had just made a snap-shutter exposure on an interesting young party playing with bean-bags in the open air. The picture was full of graceful poses and bags in mid-air, and I playfully cautioned him not to get another picture on the plate. He drew out his record book and pencilled down the memorandum, with air of one who had had some experience in that line, but, I learned afterward that, on development, there appeared upon the plate, also, the horse and buggy of a friend, hastily taken, with that obliging spirit of all

amateurs, upon a sudden call. So in the development, a plate exposed on a large stone building exhibited the startling effect of faces peering out of many of the stones, of a group that had already pre-empted the plate. Instances of the kind are numerous in every ones later as well as earlier experience, sometimes provoking but always ludicrous. A question is often asked as to the desirability of the companionship of a camera on a trip to Europe. That depends greatly on whether the camera will become the master or can be kept the servant, whether the tendency to multiply exposures, where there is so much worth taking can be restrained within anything like reasonable limits. If so, it may be a very desirable adjunct. But if it is allowed to convert a trip into a picture-taking excursion, much of the real pleasure and profit of such a trip may be sacrificed, and the pictorial results will be a poor return. On the steamer employment with the camera might prove an effective prophylactic against seasickness, or, at least, as I have found it, a great relief from the ennui of the voyage, and productive of interesting souvenirs. There are those who hesitate to take a child of three or four years, who have little doubt about their being able to manage a camera. My own experience with both is the reverse. On several occasions I have had the three and a half year old child and the camera. The latter was shipped direct to the point in Switzerland—the Zermatt region—where views, not then in the market, were desired, and there all the time and attention required were devoted to it, and it was then shipped as directly back to port on its way to America, that it might not lead into temptation along the route of travel. But the child always made the whole trip and enriched it with views peculiar to young eyes. As to the size of outfit in any case, for beginners, I invariably advise, 4 x 5, unless there are peculiar reasons for a different size, or any inclination toward stereoscopic pictures, in which case I as uniformly encourage it, and advise the 8 x 5 outfit. Many monocular views in Europe and elsewhere have a very limited value compared with that of the stereoscopic combination. Thus my own glacier views reveal almost

nothing as single pictures or lantern slides, but as stereographs possess a high value.

Great discouragement in the practice of stereoscopic photography has doubtless resulted from the fact that for so many subjects glass stereographs are almost indispensable to produce the highest effect, and these have presented peculiar difficulties in their preparation in proper position and of proper size on the glass, but I would suggest that if the recently introduced transparent flexible films are adapted to stereography, the production of transparent stereographs would be so simplified as to bring them, as far as their preparation is concerned, in competition with paper. The two binocular pictures could be printed separately, and mounted between thin cards with openings cut in them of the proper size and at proper distance from centre to centre, as I have done with mica plates. They could readily be made to fold in the middle and be sent by mail. I will only add a word upon what might be called the amateur's developer, with hydroquinone. My first trial was with Balagny's formula, with stock solutions as follows: Sulphite of soda (cryst.) 25 grammes, water 100 cc.; carbonate of soda 50 grammes, water, 200 cc.; hydroquinone 2 grammes, alcohol 20 cc. The developer was mixed from these stock solutions in proportions given. Simple in preparation, requiring few ingredients, prompt and controllable in action, suitable for plates of all makes and bromide paper as well, remaining clear and retaining its developing qualities for a month at least, in spite of frequent use, and withal inexpensive, it seemed to possess every desirable quality. A second developer, made up from the same stock solutions a few weeks later, became dark and muddy in early stages of development with the first plate. As I have received similar complaints by others, I would simply say that by the substitution of freshly prepared solution of sulphite, for the old stock solution, this objectionable feature disappeared. Doubtless the formula just given may not be the best for all purposes, but is susceptible of ready modification, and with flexible films will reduce much the trouble and uncertainties of tourist photography.

FIG. 6.—Etching showing same character of unsoundness as *Fig. 5*, but in less degree.

FIG. 7.—Etching of same type as *Fig. 6*.

FIG. 5.—Rail which broke in service, causing a wreck. Shows result of longitudinal defects in the ingot from which it was rolled.

FIG. 8.—Etching of a nearly sound rail.

FIG. 9.—Etching taken from a rail which had rendered good service, and which presents a sound and fine-grained metal.

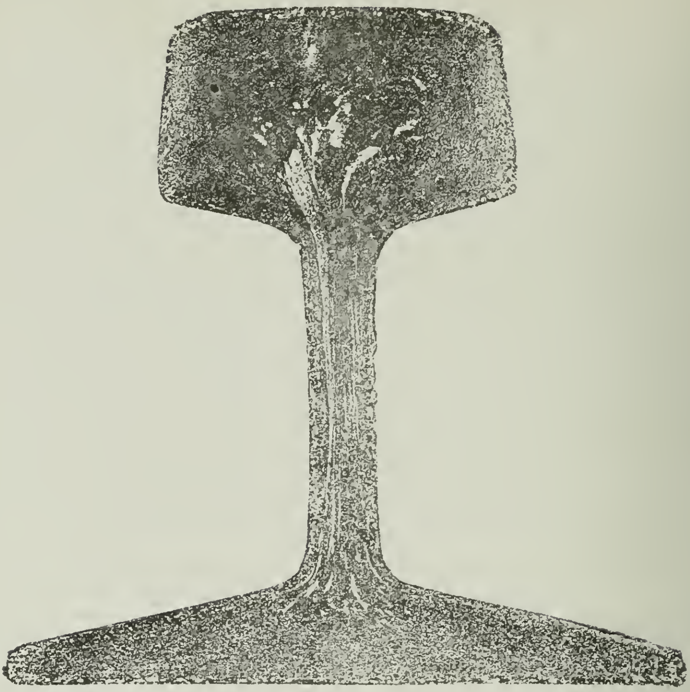


FIG. 6.—Etching showing same character of unsoundness as *Fig. 5*, but in less degree.

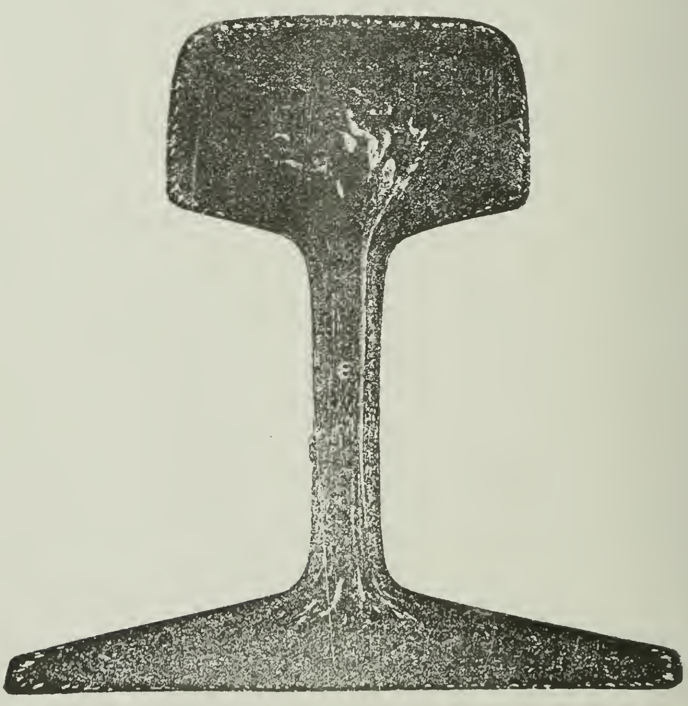


FIG. 7.—Etching of same type as *Fig. 6*.

FIG. 1.—Ingot placed on its side before interior steel had solidified.

FIG. 3.—Ingot placed on its side before interior steel had solidified.

FIG. 2.—Ingot from same conversion as *Fig. 1*, but allowed to remain on end until cold.

FIG. 4.—Ingot from same conversion as *Fig. 3*, but allowed to remain on end until cold.

FIG. 1.—Ingot placed on its side before interior steel

FIG. 2.—Ingot from same conversion as *Fig. 1*, but allowed to

THE MANUFACTURE OF BESSEMER STEELS.

BY ROBERT W. HUNT.

[*A lecture delivered before the* FRANKLIN INSTITUTE, *January 21, 1889.*]

The SECRETARY of the INSTITUTE introduced the Lecturer, who spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

It may seem strange to some of you that I should speak of Bessemer steels. All metal made by the acid Bessemer process is generally called Bessemer steel, whether the reference is made in either a commercial or technical sense. With this I have no fault to find from a commercial standpoint, but do think technically it is too general.

I remember so vividly the troubles through which the Bessemer process passed in its earlier days; and in this connection let me remark, that it is probable that many of you do not realize the comparatively little while ago those early days existed. I do not allow myself to feel old, but I know it was after the throes of our great civil war had made many of us feel that we had already played a man's part in the great drama of life, that the first heat of steel was made by the pneumatic process in America.

Many and mighty have been the changes and developments since that time, and in none, and by none, have they been greater, or assisted more, than that same process. One of the causes which for a long time operated against the general adoption of Bessemer metal, was its being all called Bessemer *steel*, without any distinction being made as to its grade. In fact, the makers in most instances did not realize the vast range of the possibilities of the process, and themselves regarded it all as one metal. It was expected to make either a good rail, razor or a good steam boiler, with an occasional jack-knife thrown in. If the particular piece of steel happened to be suitable for the razor, the

manipulator was enthusiastic over the new metal, until he tried making boilers from plates from the same lot of ingots; he then became loud in his denunciations of its utter unreliability. In fact, the new metal was expected to be all things to all men. But the Swedes have proved that good razor steel can be made in the Bessemer converter. Remember, steel rails have conquered their vast domain, and made possible the world's great railroad systems and traffic, and many good boilers have been made from metal treated by the same general process. But different steels were used in each case. In other words, good metal can be, and is, both technically and commercially, successfully made by the pneumatic or Bessemer process, having a range of from about 0·05 per cent. to one per cent. of combined carbon.

As before stated, the process is young in years, but it has had a most wonderful development in both details of operation and amount of production.

With your permission, I will give a brief résumé of its history. Henry Bessemer, while experimenting in 1854 to obtain a suitable metal for an improved cannon, became impressed with the belief that he could, by forcing air and perhaps steam through already melted pig-iron, decarbonize and desiliconize it sufficiently to produce steel and wrought iron. He therefore continued his investigations and experiments in that direction. As he progressed he became convinced of the value of his ideas, and sought to protect them by Letters Patent. He obtained his first English patent October 17, 1854, and followed it quite rapidly with others. His American patents were secured February 12th and August 25, 1856.

Bessemer's idea was to decarbonize the bath of metal down to the point which would be suitable for the grade of steel or iron he sought to make. The physical difficulties he encountered in his experiments were simply appalling; in fact, these troubles did not disappear until some years after the process had been accepted as a commercial success. As I had occasion to say some years ago in relation to these difficulties, "It has required faith made perfect to carry one through the sea which seemed to be bounded by

no shores. As I have often expressed it, if we, knowing there was a way through all our troubles, felt so hopeless, what must have been Bessemer's pluck to enable him to persevere through his difficulties, when the desired end was known only through faith?"

In addition to the physical troubles, he encountered chemical ones. It proved impossible to always stop the decarbonization at just the proper time; and generally, if the percentage of carbon was as desired, the metal was worthless from its red-shortness, the latter being caused by the presence of burnt iron, or iron oxide, which was formed by the oxygen of the blast acting on the iron during the final stages of the process.

A. L. Holley, in a lecture delivered in 1873 at the Stevens Institute of Technology, on "Bessemer Machinery," presented the following eloquent statement: "Within the sixteen years that have elapsed since Bessemer made his first trials, his process has risen from a nearly abandoned experiment to the production of a million tons of steel per year. It has, indeed, progressed, as all successful processes do—whether fast or slowly—by the constant aid of experiment and failure; but the rapidity of its development was due, in a degree not often precedented in the iron business, to the genius of its inventor—especially to that form of genius known as perseverance.

"The difficulties of the Bessemer manufacture, although great enough mechanically to require a radically new system of enginery, were not chiefly mechanical. As soon as the engineer had surmounted his obstacle, a chemical stumbling-block rose up in the way; and his discouragement was that absolute mechanical perfection might never lead to commercial success.

"The mechanical problems, however, are of an unusually difficult character. The material treated is in a *fluid* state. As a rolling-mill man fitly expressed it, 'a puddle-ball or a rail pile will lie still on the floor, if anything breaks down; but if five tons of *fluid steel* gets the upper hand of you, there's no telling where it will *stop*.' Suitably lining vessels to hold and handle the incandescent fluid, involves all the chemical

and structural uncertainties of refractory materials. Extraordinary provisions must be made against accidents, and against serious losses, if they do occur. The reserve must be unusually strong, and the line of retreat vigilantly guarded. The excessive heat of fluid decarburized iron—not less than 4,000° F.—and its violent erosive action as it boils in the converter, demand, not only hard and fire-proof linings, but provisions for quickly renewing them; and the impossibility of maintaining the temperature while the metal is being transported and cast, requires great celerity and certainty in these operations; otherwise the metal will chill into mere scrap. In many manufactures, if an important machine fails, a little delay and immediate repairs are the only loss; but here, constant readiness and certainty of action are indispensable. Ten seconds delay in turning down a converter, when a charge is blown or a tuyere fails, may involve not only the ordinary delay and repairs, but a heavy loss on the product, and extraordinary repairs on, if I may so say, innocent organizations which have been drawn into the general disaster."

Mr. Robert Mushet, of the Forest Steel Works in England, investigated the matter and solved the great chemical trouble, by carrying on the process until practically all the carbon had been burned out of the charge, and then adding enough carbon to give the desired result, and at the same time adding manganese in a metallic form, which from its affinity for oxygen would unite with the oxygen of the burnt iron present in the bath, thus restoring such iron to a metallic state, and so taking away the red-shortness which had been so fatal to the sound working of the metal. By this invention the Bessemer process became practical.

Mr. Mushet was granted an English patent on September 22, 1856, but so little did he realize its value, that being financially depressed, he allowed it to lapse in the third year. Fortunately for him he had taken out an American patent, dated May 26, 1857, from which, owing to our laws being better calculated to protect inventors, he has received some pecuniary reward. And honor is due to Bessemer for having, after his own enrichment, settled on Mushet an

annuity of £300. The British Iron and Steel Institute awarded Mushet in 1876 their Bessemer gold medal. The English government bestowed the honor of knighthood on Bessemer and from the royalties accruing from his patents he has received several millions of dollars.

During these first years the Bessemer process was not regarded as a success, and perhaps nothing did so much to both encourage its inventor and assist him in obtaining pecuniary backing, as the success obtained from the process in Sweden. Fortunately the ores of that country were low in sulphur and phosphorus, and had some manganese. They were smelted with charcoal, and the resulting pig-iron was of exceptionally pure character, containing enough manganese to render it possible to make sound Bessemer metal without the addition of manganese after the conversion. Goran Frederick Goransson, of Sweden, accomplished this with such success and in such quantities in 1858 that Bessemer was, as before stated, not only encouraged to further efforts, but was also furnished with the argument no doubt much needed, "The Swedes are doing it!"

In relation to this, Akerman says, in his exhaustive report on the "State of the Iron Manufacture in Sweden," Stockholm, 1876: "The Bessemer method of refining has been used in Sweden from its first origin, and it is even doubtful if this process, now of so extraordinary importance, would ever have been developed, if Herr F. Goransson had not immediately after the publication of the patent, applied himself with such determination to carry out exhaustive experiments with it. For, thanks to the raw material employed, which was poor in phosphorus and in other respects of specially good quality, a completely satisfactory Bessemer product was obtained at an earlier period in Sweden than in England, and the condition of success so important for this process, that only materials poor in phosphorus are suitable for it, was ascertained."

Bessemer was not the only one whose investigations were directed towards the effect of blowing air through melted cast iron. In fact the old finery-fire process was a well-known and wide-spread example, and it was to be

expected that further development should be sought. Joseph Gilbert Martien, of Newark, N. J., but living in London, England, was allowed an English patent, September 15, 1855, for refining iron by blowing air and steam through it as it ran in troughs, while being conducted from the blast furnace in which it had been made.

William Kelley, of Eddyville, Ky., had been for some years experimenting at his works with new applications of air for refining purposes, and succeeded in commercially making in a few minutes refined metal, which had taken some hours to produce in the old finery, or run-out fires. He also obtained, experimentally, some malleable metal. He also spent all of his own money and all he could borrow.

Bessemer taking out American patents covering the principles which Kelley felt he had discovered, awakened him to the importance of protecting his rights. His application resulted in interferences with Bessemer's patents being allowed by the Patent Office, and subsequently the issuing to Kelley of patents dated January 10, June 23, and November 3 and December 22, 1857. His action prevented Bessemer receiving any remuneration from his American patents, on the process, but did not affect his mechanical patents. He subsequently sold all of them to Messrs. Winslow, Griswold and Holley, of Troy, N. Y., and Kelley received his pecuniary reward through the sale of his patents to the Kelley Pneumatic Process Company, which organization also acquired Mushet's American patent. As is well known these interests were all consolidated in 1866.

Mushet made his first heat of good Bessemer steel by the addition of spiegeleisen at the Forest Steel Works in 1857, casting it into small ingots, and the steel was used for tool purposes. This was before Bessemer or his associates had made pneumatic steel in commercial quantities.

During the years from 1854 until the new process was firmly established, the iron metallurgical world was greatly disturbed by rumors of what was being accomplished by various parties, and at many works experiments were made.

Percy relates that had it not been for an accident most

likely Bessemer would have lost the honor of his discovery. In October or November, 1855, two or three months before the issuing of Bessemer's first patent, George Parry, of the Ebbw Vale Iron Works, fitted up the hearth of a reverberatory furnace with a series of pipes in which many holes had been drilled. Plugs were inserted in these holes, and the pipes carefully covered with refractory material, which was dried, the resulting cracks filled up and then the plugs withdrawn. This system of pipes was connected with the blast from a blowing engine, the furnace brought up to a high heat and a charge of melted iron run into it, the blast having been first turned on. By some accident a leak occurred in the furnace, before the process had continued very long, and the metal ran out on the ground. Mr. Parry wanted to make another trial, but the proprietors of the works objected, and so Bessemer's glory was saved to him.

While Mushet was waiting for the completion of his small converter at the Forest Works, he obtained, early in 1857, some Bessemerized metal, or metal which had been desiliconized and decarbonized by the Bessemer process, from the Ebbw Vale Works, and remelted it in ordinary steel crucibles, putting forty-four pounds in each, to which, when melted, he added two pounds of melted spiegeleisen. He cast ingots, weighing some 500 to 600 pounds, and from one of them had a double-headed rail rolled at the Ebbw Vale Iron Works. This was put in the track of the Midland Railroad at Derby Station, at a point where iron rails had lasted but a few months. The steel rail remained in this service until June, 1873, after successfully withstanding the passage of over one and a quarter million trains. This was undoubtedly the first Bessemer steel rail, if it can be rightly so-called, ever put into service, and I know of no record of a previous one having been rolled.

Notwithstanding the reported success of the process in Sweden, and the attention which it had attracted in England, it met with much opposition, and many authorities of note did not hesitate to predict its failure. I can readily understand how a prudent engineer, to say nothing

of a sensitive capitalist, must have felt grave doubts about its success after witnessing one of the "messes," which, for so long a time, were such prominent and persistent features of the process. The percentage of waste and scrap often exceeded that of the metal which was gotten into ingots, while it was almost an even thing whether or no the metal of those ingots was of the grade desired. So it was not until 1863 that active steps were taken towards the introduction of the process into America. In that year, the Kelley Pneumatic Process Company was organized, and they soon commenced the erection of experimental works in the casting-house of a blast furnace at Wyandotte, Mich., and in these works, in the fall of 1864, the first American pneumatic, or Bessemer steel, was made, the works being under the charge of Mr. William F. Durfee.

The first steel rails made in this country were rolled at the old or north side mills of the North Chicago Rolling Mill Company, on May 24 and 25, 1865. This was simply an experimental rolling of six rails from steel made at the Wyandotte Works. The first commercial rolling of steel rails did not occur until August, 1867, when the Cambria Iron Company, at their mills, in Johnstown, Pa., executed an order for the Pennsylvania Railroad Company, from steel made by the Pennsylvania Steel Company, at their works, near Harrisburg, Pa.

From that time on the advance has been rapid, and the development so great, that the history of the early days seems like a dream.

In our country's centennial year, I relieved my patriotism by reading in this very hall a paper before the American Institute of Mining Engineers on the "History of the Bessemer Manufacture in America." In it I gave with great pride the largest yields which had been made by the various American Bessemer works, and compared them with what eight years before had been considered satisfactory results, when 10,000 tons of ingots was named as the maximum annual output of two five-ton converters. I find on referring to that "History" that, while all had records of which to be proud, the North Chicago Rolling Mill Com-

pany headed the column; their banner results being 330 gross tons of ingots for twenty-four hours; 1,583 gross tons for the week, and 6,457 gross tons for the calendar month.

To-night, some twelve years later, I can give figures quite as startling in comparison with these, as they were in relation to the early records. If I am correctly informed the largest output ever reached by any Bessemer plant, to say nothing of being produced in two converters, was that of the Union Steel Company, of Chicago, in May, 1888, when, in their two ten-ton converters, they made the following record: Best twenty-four hours, 1,448 1000/2240 gross tons; best week, 6,271 gross tons; calendar month, 28,145 1640/2240 gross tons of ingots. In the same month they rolled on one rail train 22,808 0799/2240 gross tons of rails. While this gave them the "broom," their tenure is a precarious one, as they beat the best work of several other American plants by a somewhat limited margin.

I find one singular fact to exist in this connection, and that is, in my "History," previously mentioned, I say, in speaking of the North Chicago Works: "The first blow was made on April 10, 1872, under the direction of Mr. Robert Forsyth. * * * This gentleman has ever since remained in charge of the converting works, and has been most eminently successful in his management. His works are to-day making the largest output of any in the world." And I must now say to you that the Union Steel Works, of Chicago, were designed and built, and have ever since been operated under the management of the same gentleman. The only way I can account for this instance of "history repeating itself," is by again quoting from my history, where I said, he "had received his Bessemer education at the Troy Works."

The product of Bessemer steel in Great Britain and the United States for 1887 is given by James M. Swank, General Manager American Steel and Iron Association, to have been 5,025,436 gross tons; of which the United States made 2,936,033 tons, or more than one-half.

In 1888 it was much less, owing to the want of demand. The totals of ingots have not yet been ascertained for either

country, but the United States made 1,364,337 gross tons of rails.

In 1887, the question put to the managers by the commercial ends of the Bessemer steel-producing organizations was: "Can you make all we can sell?" In 1888, unfortunately for the pecuniary returns of the business, the same gentlemen informed the same managers that: "We can't sell what you can so easily make." I expect, if such had not been the case, Messrs. Fritz, Jones, Bent, Smith, Potter, *et al.*, would have compelled Mr. Forsyth to have made another record to have retained the lead. Hence, we may expect new best figures the next time we have the pleasure of discussing the question. There does not seem to be any limit.*

Chemical knowledge and investigation early played a prominent part in Bessemer history. Unfortunately the processes of the analysts had not then reached the same refinement of determination which they possessed later. Hence, what were then called "traces" are now accurately determined and found to be of sufficient quantities to account for some of the early unsatisfactory and inexplicable results.

After the application of Mushet's invention, and the

* As anticipated, the output of the Union Steel Company has been surpassed by both the North Chicago Rolling Mill Company, under the management of E. C. Potter, Vice-President, and the Edgar Thomson Steel Works, directed by General Manager Capt. Wm. R. Jones.

In January, 1889, North Chicago produced:

Gross tons of ingots,	27,427
Gross tons of rails,	22,976

Their best work for twenty-four hours was:

Gross tons of ingots,	1,393
Gross tons of rails,	1,248

which is still the best on record.

In March, 1889, Edgar Thomson made:

Gross tons of ingots,	31,120 900/2240
Gross tons of blooms,	27,790 1420/2240
Gross tons of rails,	25,342 2008/2240

This gave that works the "broom." Will they keep it?

April 17, 1889. R. W. H.

development of Bessemer's mechanical devices, and the practical determination of the proportions of certain chemical elements which rendered some irons unfit for the process, the minds of metallurgical investigators of both hemispheres were directed toward the solution of the problem as to how those impurities could be eliminated. As you know, phosphorus was the element exerting the most powerful and persistent influence, and unfortunately the largest proportion of the world's available iron ore supply contains too much of that substance to permit the use of metal made from it in the ordinary Bessemer process. In it, phosphorus is increased to the extent of the loss incidental to the operation.

Much time and money have been spent on this problem. Chemistry taught that it was impossible to eliminate phosphorus in the presence of an acid slag, and that it was equally out of the question to have a basic one, so long as you protected your converter with an acid lining. Therefore, all required was to substitute a basic one. That was easily done, but the trouble was to find such a lining which would resist the fluxing action of the charge while being decarbonized and desiliconized. In this search was spent much money and more time.

The well-known chemist and metallurgist, George J. Snelus, of England, was the first to nearly reach practical success, and he patented his invention in 1872. But it was some five years afterward that Sidney Gilchrist-Thomas, assisted by his cousin Percey C. Gilchrist, was rewarded for their exertions by making an absolute success of dephosphorizing iron in a Bessemer converter, by lining the same with lime, and adding lime to the melted iron. This they patented November 22, 1877. These gentlemen soon consolidated their interests with Mr. Snelus. The process is known as the "Thomas-Gilchrist or Basic Process." The solution of the difficulties in making the linings and bottoms of the converters resist the action of the charge, was in the character of limestone used and the manner of preparing it. But it was also discovered that the pig-iron to be treated must also be within certain chemical proportions.

In the regular Bessemer, or acid process, the burning out of the silicon of the iron treated is largely depended upon to furnish the necessary heat to keep the metal sufficiently liquid, while being subsequently cast into ingots, to avoid loss from "sculls" and other scrap, consequent upon its chilling. But the chemical action of the silicon is very severe on the lime linings, and as it was found that the elimination of phosphorus caused heat, it therefore became manifest that the metal best adapted to the basic process was one high in phosphorus and low in silicon.

The keeping up of the basic linings, lessening of product, and other details of the basic, requires that the pig metal used must cost from two to three dollars per ton less than that used in the acid, to place the two processes on an equal commercial basis, leaving out of consideration any question as to the relative value of their resultant metals.

The Thomas-Gilchrist Process is extensively used in Europe; the greatest development being in Germany. As yet it has not made much headway in the United States. The Pennsylvania Steel Company some years ago made some experiments with it in their old or original Bessemer plant; and since then Messrs. Morris, Wheeler & Co., have built a regular basic plant at Pottstown, Pa. Of course, these companies met with the usual troubles incident to the introduction of a new process, but I suppose the greatest difficulty has been their inability to obtain suitable irons at a sufficiently low price.

After the application of Messrs. Thomas & Gilchrist for American patents, Jacob Reese, of Pittsburgh, urged his claims for priority of invention, and it resulted in Letters Patent being granted him. Considerable litigation has ensued, and no doubt the uncertainty attending the legal status of the process has had a restraining influence on the establishment of basic works in the Southern States, where it would seem suitable iron could be cheaply produced.

There have been numerous other patents allowed, but they have failed to attract much attention.

As is well known, rails have absorbed the largest proportions of metal made by the Bessemer Process. But from the

very beginning other grades of steel have been produced with greater or less success. The Swedes have continued since Goransson's early experiments, to make good metal of both high and low carbon in their various forms of Bessemer converters. No doubt many of you recall the wonderful and beautiful Swedish exhibit in our Centennial. We there had steels made by the Bessemer Process worked up into many forms, from heavy forgings to the most incisive cutting instruments of domestic life, surgery and war.

The stagnation in the rail business at various periods, and the constantly increasing production, have been, and are a constant pressure toward putting the output of the converters into some other form. I devoted much attention in this direction while in charge of the Troy Works, and met with some degree of success.

In regard to whether certain rails are of the best quality or otherwise, generally a considerable period of time must elapse before the question can be definitely answered, but with so-called special steels, the determination is reached much quicker; hence, if your metal does not make good drills, cutlery, springs, gun barrels, drop forgings, etc., the maker hears from it very soon in a manner not at all pleasant, and he has much less opportunity to talk back, than when treating with his railroad friends.

Observant steel makers have long realized the influence of temperature on the quality of steel while it is being made, quite as much as during its subsequent manipulations. This is true whether the process is conducted in the crucible, open-hearth furnace, or Bessemer converter. But I think the Bessemer people have not generally been as alive to the importance of this fact as their brethren of the other processes.

Dr. Thomas M. Drown, in his paper on, "The Latest Development of the Bessemer Process, or the Blowing of Small Charges," read before the Society of Arts, Massachusetts Institute of Technology, May 27, 1886, treats very intelligently and interestingly on this subject. But he devotes his attention to soft steels or ingot irons, giving results obtained by the Avesta, Prevali, and Clapp-Griffith

converters. I do not venture to dignify any of them as processes. Perhaps my friend, Harry W. Oliver, will appreciate the cause of my timidity.

Let me, at the same time, say, that where it has been intelligently conducted the Clapp-Griffith converter has continued to yield satisfactory results.

However, the importance of temperature is not confined to the production of soft metal, it extends up the whole range of carbons.

I believe now, as I have always, that the more nearly you can have metal composed of only iron and carbon, the closer you will be to the ideal. Unfortunately in this, as in many other human matters, we cannot attain that sublime altitude, and so must be content to do the best we can with that which is vouchsafed us. If we can make one impurity offset the bad effects of another, we will accomplish the results which will be more orthodox in the metallurgical, than the religious world.

As we are forced to put up with the presence of silicon, sulphur, phosphorus, and manganese, we must endeavor to compel as many of them as possible to be our allies. Leaving phosphorus out of consideration, we will first consider the effects of silicon. This element is recognized as valuable in rendering steel castings sound, or free from "blow-holes," but has been generally regarded with disfavor by other steel makers. I do not fully agree with them in this condemnation, when other than the very soft or high phosphorus metals are considered. Some years ago I made quite a full investigation of the composition of various steels of approved brands, and which had given satisfaction to many users for various purposes. I was particularly interested in my silicon results, and I herewith present some of them.

A sample of what was known as New England hoe steel, used with satisfaction by Messrs. Lane, Gale & Co., in making their celebrated "Planters Hoes," gave:

Carbon,	0·76
Silicon,	0·185
Phosphorus,	0·059
Manganese,	0·441

The same firm gave me a sample of another steel which they designated as "scarf steel. It contained:

Carbon,	0 52
Silicon,	0·150
Phosphorus,	0 068
Manganese,	0·406

The Providence Tool Company of Providence, Rhode Island, at that time filling large contracts for rifles for the Turkish government, used for the "circles and plungers" of the gun:

Carbon,	0·66
Silicon,	0·171
Phosphorus,	0·057
Manganese,	0·416

The Hartford Machine Screw Company used a steel containing:

Carbon,	0·46
Silicon,	0·223
Manganese,	0·316

Messrs. Huntly & Babcock of Utica, N. Y., liked a brand of steel for making hoes, with the following composition:

Carbon,	0·61
Silicon,	0·158
Phosphorus,	0·086
Manganese,	0·445

For "Pitch" and other large forks their steel gave:

Carbon,	0·63
Silicon,	0·241
Phosphorus,	0·073
Manganese,	0.610

The Remingtons gave me samples of steel which they liked for making "Planters'" hoes, which analyzed:

Carbon,	0·52
Silicon,	0·150
Phosphorus,	0·043
Manganese,	0·376

For "goose-neck" hoes:

Carbon,	0·53
Silicon,	0·249
Phosphorus,	0·040
Manganese,	0·413

In spring steels, I found "Jenk's" English, a favorite brand, had:

Carbon,	0·64
Silicon,	0·145
Phosphorus,	0·088
Sulphur,	0·005
Manganese,	none

A second sample obtained from another user gave:

Carbon,	0·52
Silicon,	0·150
Phosphorus,	0·060
Manganese,	0·034

One sample of "Greaves" Swedish spring steel analyzed:

Carbon,	0·53
Silicon,	0·110
Phosphorus,	0·030
Sulphur,	0·015
Manganese,	none

Another sample:

Carbon,	0·76
Silicon,	0·84
Phosphorus.	0·018
Manganese,	0·085

Naylor's spring steel, from the Bridgeport, Conn., Works, contained:

Carbon,	0·65
Silicon,	0·185
Phosphorus,	0·102
Manganese,	none

Leaving these, which may be considered of the coarse grades of steel, we will consider steel used by the Johnsville, N. Y., Axe Works for hatchets. It analyzed:

Carbon,	0·70
Silicon,	0·270
Phosphorus,	0·041
Manganese,	0·195

A steel used by Ames & Co. for making swords had:

Carbon,	0·64
Silicon,	0·258
Phosphorus,	0·017
Manganese,	0·453

A. S. Millard, a celebrated maker of scythes, gave me as representing a German brand of steel, which he had used with the utmost satisfaction for thirty years, a sample which contained:

Carbon,	0·63
Silicon,	0·127
Phosphorus,	0·056
Sulphur,	0·005
Manganese,	0·212

Of cutlery steels, Messrs. Sanders, Ferry & Clark, New Britain, Conn., gave me "knife" steel having:

Carbon,	0·51
Silicon,	0·18
Phosphorus,	0·029
Manganese,	0·265

"Fork" steel:

Carbon,	0·49
Silicon,	0·335
Phosphorus,	0·03
Manganese,	0·444

Also a sample of Park Bros. & Co.'s, cutlery steel, containing:

Carbon,	0·61
Silicon,	0·210
Phosphorus,	0·046
Manganese,	0·402

Messrs. Park Brothers' Black Diamond Tool Steel, which then sold at fourteen and one-half cents a pound had:

FIRST SAMPLE.

Carbon,	0·88
Silicon,	0·220
Phosphorus,	0·023
Manganese,	0·14

SECOND SAMPLE.

Carbon,	0·85
Silicon,	0·204
Phosphorus,	0·022
Manganese,	trace

Frith's English tool steel contained:

Carbon,	0·85
Silicon,	0·19
Phosphorus,	0·022
Manganese,	0·174

Another sample of Park Brothers' Black Diamond Tool Steel analyzed:

Carbon,	0·86
Silicon,	0·216
Phosphorus,	0·030
Manganese,	0·091

I have before related that while I was making these investigations, and at the same time endeavoring to produce in the Bessemer converter steels to take the place of those, or as it was apt to be commercially put, "fill the bill at a less cost," I made a visit to the works of a firm, the members of which were and are highly esteemed by me, and whose products of the higher grades of steel have the very highest reputation. These gentlemen have always been progressive, and therefore their utterances are not likely to be controlled by prejudice; hence carry with them great weight. On the occasion of my visit I was full of what I was accomplishing in my converter. They treated me kindly, but said I must not expect too much. That in making the harder steels I would find silicon my constant enemy. As they happened, while we were talking, to be testing a piece of their own steel which was yielding splendid results, one of them said

to me: "My dear fellow, when you can make such steel as that in your Bessemer converter we will begin to believe in it." I was thrown into a depressing state of humility and could with difficulty muster courage to beg a piece for analysis. It was most cheerfully given. The result was:

Carbon,	0·86
Silicon,	0·306
Phosphorus,	0·016
Manganese,	0·195

About this time several American makers of rifles and pistols were filling European contracts for both the Russian and Turkish governments. Most of them were using foreign iron and steel; the iron being of special brand known as "Marshall." Supplying the requirements of these firms presented a tempting field, and we devoted ourselves to it. It did not prove such an easy matter as we fondly hoped, and it was only after numerous trials and some failures that we attained success. But we soon learned that to give a satisfactory gun-barrel steel, the manganese must be kept somewhat low. Increasing it might make the steel sound and roll well, but it also caused it to throw a long chip before the drilling tool. This was very objectionable, as such chips would throw the necessarily long and slender drills out of line, and thus cause them to run to one side of the rifle barrel. A very satisfactory metal had the following composition:

Carbon,	0·29
Silicon,	0·212
Phosphorus,	0·048
Sulphur,	0·065
Manganese,	0·370

It is well known that manganese has a strong influence on the tempering characteristics of steel. Therefore, it must not be in excess in any metal which will be tempered. It causes water-cracks and other undesirable qualities.

In considering rail steel, I will not trespass on your time and patience by going over the history of the steel-rail business, although familiarity with it is necessary to fully understand some of the points bearing on the manufacture of rail steel.

Suffice it to say that we have good reason to feel that all rails are not as good as they ought to be. Perhaps, regarded in the same light as wearing apparel, they are good enough for the money paid for them, but as rails, some rails ought to be better.

I have dwelt somewhat on the chemical composition of steels, and but briefly referred to the effect of the physical features of their manufacture. Let us return to that branch of our subject. When general attention was first called to the somewhat unsatisfactory results which were being obtained from the wear of the rails made during the later years, great stress was put upon their chemical composition, and chemical analysis was expected to tell the cause of the trouble. This branch of investigation was followed, and several interesting and ingenious theories built up. But unsatisfactory rails continued to be made, and the analyses of those which had yielded good service demonstrated that many of them were at variance with the theories, and also that their chemical composition was like many that had failed—in fact, did not have any uniformity, but ran through almost the entire gamut—it would seem that some other than chemical causes must be sought to account for their good wear and the bad behavior of others.

Rails made by John Brown & Co., of England, and put down on American railroads some years ago, have been generally held up as ideal rails, and the American makers for a long time supposed that when these rails did wear out, so that they could be analyzed, the secret of their good service would be told. As illustrative of how little regularity or purity of chemical composition influenced their wear, I call your attention to the analyses of thirteen John Brown rails, all of which had filled years of faithful service, and been selected as bright examples of what good rails should be.

	Carbon.	*Silicon.*	*Phosphorus.*	*Sulphur.*	*Manganese.*	*Copper.*
1	0·35	0·08	0·128	0·068	0·742	0·048
2	0·39	0·071	0·156	0·155	0·662	0·32
3	0·36	0·103	0·125	0·060	0·815	trace
4	0·70	0·306	0·111	0·058	0·681	0·016
5	0·36	0·069	0·153	0·131	0·621	0·043

	Carbon.	*Silicon.*	*Phosphorus.*	*Sulphur.*	*Manganese.*	*Copper.*
6	0·44	0·208	0·098	0·059	1·046	none
7	0·45	0·102	0·128	0·105	0·616	0·056
8	0·36	0·087	0·148	0·181	0·625	none
9	0·24	0·068	0·131	0·104	0·645	0·008
10	0·37	0·051	0·098	0·050	0·639	trace
11	0·32	0·089	0·145	0·077	0·745	trace
12	0·35	0·069	0·077	0·099	0·945	none
13	0·28	0·032	0·084	0·053	0·312	none

You will observe that the carbons ranged from 0·24 to 0·70; silicon, from 0·032 to 0·306; phosphorus, from 0·077 to 0·156; sulphur, from 0·050 to 0·155; and manganese, from 0·312 to 1·046. These thirteen rails taken as a whole were chemically a "poor lot," but physically most excellent. As these results are fortified by many others, we are compelled to think that physical peculiarities of their manufacture must account for their superiority.

In a paper on "Steel Rails and Specifications for their Manufacture," which I had the honor of reading before the American Institute of Mining Engineers, I gave instances of rails having practically the same chemical composition and of the same sections in the tracks of the same road and subjected to the same conditions, which had given opposite results. To repeat one example; a rail wore *soft* which analyzed:

Carbon,	0·39
Sulphur,	0·059
Phosphorus,	0·085
Manganese,	0·722

While another wore *hard* and contained:

Carbon,	0·40
Sulphur,	0·064
Phosphorus,	0·080
Manganese,	0·779

I also took the position that rail sections were largely responsible for the good or bad wear of the rails rolled to them. I will not now repeat my argument on this point; but one thing is certain, no matter how good the section may be, we cannot expect satisfactory results unless the

steel going into it is properly treated in all the stages of the rail's manufacture.

First, the temperature of the conversion must be controlled. Second, the recarburizer must be thoroughly mixed throughout the mass of blown metal. Third, time and opportunity must be allowed for the escape of the confined gases. Fourth, care must be exercised in pouring or casting the ingots; not only in keeping the steel from spattering against the sides of the ingot moulds, but also that the final manner of pouring each ingot shall act as a sink-head, and the gases allowed to escape so that an excessive length of spongy tops to the ingots shall not be made. Fifth, the ingots must not be taken from a perpendicular position until the interior steel has had time to solidify. Sixth, the steel must not be overheated in the heating furnace, of whatever form it may be, either while in the shape of ingots or blooms. Seventh, all defects should be carefully cut off and out before the steel is put into finished shape. Eighth, the temperature of the metal while receiving the final passes, or reductions in the rolls, should be low.

Observe these rules, and the steel of 1889 will be just as good as that of 1868. The early makers did not know so much more than the present ones. They knew much less. In fact they blindly followed as closely as possible the traditions of older processes. There had not yet been any made for this one. We do not want to advance backwards, but we will not gain by casting away that which has proven to be good, unless we can replace it by something better.

To return to the manner of casting ingots, and the importance of keeping them in an upright position until the interior metal has solidified. Rails have failed at the ends by crushing down and splitting, sometimes the one or the other, other times both. The usual reason given has been that enough steel was not sawed off the end of the rail after it was rolled. When this statement was made, during the somewhat celebrated Dudley steel-rail discussion before the Mining Engineers, Dr. Dudley replied, that he had found rails on the Pennsylvania Railroad which would have required being cut in two in the middle and both ends

thrown away; and he undoubtedly was right, for many rails have crushed and split at other points than the ends. But we did not seem to be able to account for it so frequently happening.

Last summer Mr. Robert Forsyth, General Manager Union Steel Company, made some investigations as to the effect of placing ingots on their sides before the interior steel had solidified. From a number of heats he had one ingot drawn from the casting pit as quickly as possible and laid on its side; while the next ingot to it was allowed to remain in an upright position. These ingots when cold were broken under a drop, and photographs taken of the pieces. Mr. Forsyth has kindly placed these at my disposal, and we will have some of them thrown upon the screen, and I hope the pictures will be plain enough for you to appreciate the difference in the character of the several ingots. Please remember that they are in pairs from the several heats of steel, so that the same history applies to both up to the time of being drawn from the casting pit. It is true that Mr. Forsyth was hoping to sustain the theory that ingots should remain on end, and so we most likely have presented extreme cases, but even if so, it is shown what can occur.

Figs. 1 and *3*, of Plate I, are of ingots too quickly thrown upon their sides, while *Figs. 2* and *4*, of Plate I, are of their companion ingots which had been allowed to stand on end until cold. In the former are plainly shown the longitudinal cavities, formed by the settling of the interior liquid steel; while in the latter these cavities become cup-shaped at the top ends of the ingots and can be cut off. They are coated with iron oxide and will never entirely weld up during the subsequent working of the steel. Had more time been taken in casting these ingots, both the longitudinal and top cavities would have been less; but, as before stated, these broken ingots illustrate dangers to be carefully avoided.

Following these (see Plate II) we have sections of rails which were undoubtedly rolled from ingots with such longitudinal defects. *Fig. 5* is from a photograph of a broken rail which caused a wreck. In this case the thinnest wall

of steel surrounding the cavity happened to form the top of the rail, and it split open. *Figs. 6* and *7* are from etchings of rails, which plainly show the same character of defects. In *Figs. 8* and *9* we have etchings from sound, close-grained rails; *Fig. 9* showing better than *Fig. 8*, and it has proven its good character by some years of faithful service.

I could repeat these by the hundreds, but it would be needless repetition and waste of time.

I am indebted to F. A. Delano, of the C. B. & Q. R. R. Co., for many etchings of rail sections—these among others—and feel confident his careful investigations will result in valuable additions to our knowledge.

The development of the Bessemer manufacture has been most wonderful in the increase of production and lessening of cost. I believe the present, while a lull exists in the demand, is a good time to consider means looking toward the maintenance of the quality of the product on a higher plane. Having so completely mastered the mechanical difficulties, such results can be reached without adding but a trifle, if at all, to the cost of the finished steel. Care is always true economy. If cost of production is seemingly increased by more time being taken at certain points of manufacture, I believe that it will be more than made up by the lessening of repairs and wear and tear, and, in fact, the time itself will be recovered at other stages of the operation.

There is one remarkable thing connected with the American history of this process. From the very first there has existed the greatest professional rivalry between the various works; at the same time the warm personal friendships for each other of those having the works in charge have never been broken. Always willing to exchange ideas and experiences, and then each using the benefit of them to push ahead, and this understood and acquiesced in by all.

While the loved and lamented Holley lived, he spread his all-loving nature over all of us. Since his death it would seem as though his spirit was still here to protect this process for which he did so much, and to shield the happiness of those who loved him so well.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

THE MIMEOGRAPH DUPLICATING SYSTEM AND APPARATUS.

[No. 1410.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 1, 1888.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

THE MIMEOGRAPH DUPLICATING SYSTEM AND APPARATUS, OF THOMAS A. EDISON, OF MENLO PARK, N. J.,

Report that: The application is made under date of August 15, 1888, by F. Z. Maguire, General Agent for Pennsylvania.

The apparatus is called the Mimeograph, and is intended to be used for duplicating autographic and type-written work, drawings, music, etc. In its operation it is claimed to be an improvement on pre-existing methods of duplicating, including some new features. The principle employed is not new, consisting in puncturing a sheet of paper or similar material with small holes along the lines to be reproduced, thereby making a stencil. This is placed on the surface to be printed, and a coloring material rubbed or pressed on it, so as to be forced through the holes on to the surface below, which is thereby printed.

The apparatus for autographic duplicating, and the operation may be described as follows: There is a hardened steel plate, the surface of which is covered with fine points, to the number of about 200 to the square inch, formed by scoring it with grooves. This plate is made one and one-half inches or three inches wide, and long enough to extend across the width of the stencil sheet, which is to be prepared, and it is set in one end of a convenient wooden frame. A slab of slate, or other suitable material, is set in the

remaining portions of the frame, the top surface of all being flush, and making a level bed. The stencil sheet, which is a thin paper covered with paraffine, is laid on this bed. the part of it to be written on being kept over the steel plate. The writing or drawing, which it is desired to duplicate, is then done with a smooth pointed steel stylus, which is used with about the same pressure and ease as a lead pencil. As the stylus passes over the stencil paper the latter is pressed down on the steel points, so that they are driven through it, making numerous small holes along the lines which the stylus traverses. The stencil thus prepared is placed between the two frames, one of which slides within the other, and is clamped down, so that the stencil is thus stretched smooth and securely held. These frames carrying the stencil are then hinged at one end to the bed, the sheet to be printed is placed on this bed and the stencil brought down upon it. An ink roller, covered with semi-fluid ink, is then passed over the stencil, pressing the ink through the holes which have been pierced in it, down on to the paper below, thus making the desired impression upon it. Printing may de done in this way very rapidly, at the rate of several hundred an hour, and one stencil may be used for as many as 3,000 copies before it is worn out by the enlarging of the holes.

To prepare a type-written stencil: The edges of a sheet of paraffine paper are folded over a piece of coarse silk cloth, back of which is laid a stiffening sheet. They are then passed through a typewriter in the ordinary way, except that no ribbon is used. The type strikes the paraffine paper, driving it against the silk cloth, which is termed "perforating silk." Wherever the type strikes, the paraffine is taken up by the cloth on the other side, and owing to its coarse texture, small holes are pierced through the paper in the lines of each letter. Copies as good as actual type-written work are taken from the stencil thus made by placing it in the printing frame and using the inking roller as before described. From 1,000 to 1,500 copies may be made from one stencil. The type is not at all injured, as in some processes, merely needing occasional cleaning.

The sub-committee has examined the apparatus, its operation and the work produced, and is very favorably impressed with the results obtained. It has also made some investigations into other methods of preparing stencils for printing, and in no instance in the comparison has its judgment been unfavorable to the mimeograph. The method employed of puncturing the stencil sheet from below upward, by pressing upon a slab covered with numerous small points, is believed to be original and worthy of special commendation. Perforations so made, being largest toward the surface to be printed, make a fuller and more continuous line than those made from above. The apparatus is deemed very useful for the purpose for which it is designed, and the Sub-Committee recommend the award of the John Scott Medal to the inventor.

[Signed] W. R. WHARTON,
JOHN R. MCFETRIDGE,
WM. MCDEVITT.

Adopted January 2, 1889.

[Signed] S. LLOYD WIEGAND, *Chairman.*

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, April 16 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 16, 1889.

Mr. H. PEMBERTON, Jr., President, in the Chair.

Members present: Dr. H. W. Jayne, Dr. Wm. H. Wahl, Dr. E. F. Smith, Dr. S. C. Hooker, Dr. H. F. Keller, Dr. D. K. Tuttle, Prof. Henry Trimble, Prof. R. L. Chase, Prof. N. Wiley Thomas, Messrs. T. C. Palmer, Reuben Haines, J. H. Eastwick, W. L. Rowland, W. W. McFarlane, W. H. Bower, F. Lynwood Garrison, Lee K. Frankel, A. W. Allen, Dr. Wm. C. Day and three visitors.

The Treasurer made a brief report, stating the present condition of the finances of the Section.

The following gentlemen were nominated for membership in the Section: Dr. L. I. Morris, 2505 Oxford Street, Philadelphia; Dr. Persifor Frazer, Drexel Building, Philadelphia; Mr. Fred. E. Ives, corner of Ninth and Filbert Streets, Philadelphia; Mr. Theodore D. Rand, No. 17 South Third Street, Philadelphia.

The President called attention to the contradictory character of two of the by-laws and recommended correction; he also recommended that one member instead of two, as at present required, be sufficient to nominate a candidate for membership.

The resignation of Dr. Isaac Norris, of 1424 Walnut Street, Philadelphia, was accepted.

The President called the attention of the Section to the fact that copies of the papers read at the last meeting had been sent as advance sheets by the Secretary to various chemical journals in the United States and abroad.

Dr. Wahl recommended that the Section continue subscription to *Fittica's Jahresbericht* recently purchased by the INSTITUTE; on motion it was unanimously voted to adopt this suggestion.

Upon the recommendation of Dr. Jayne it was decided to consider Mr. Pedro G. Salom as a member of the Section from date.

Dr. S. C. Hooker then read a very interesting paper, in which he gave the results thus far obtained in a series of sanitary analyses of the hydrant water supply of Philadelphia. These analyses include determinations of chlorine, of free and albumenoid ammonia by the Wanklyn process and nitrogen in nitrates, according to the carbazol method devised by him. These analyses are to be systematically conducted at regular intervals in the future, and the results are to be embodied in future papers to be published in the JOURNAL OF THE INSTITUTE.

This paper called forth a very active and interesting discussion, which was participated in by many of the members present.

Mr. Haines suggested that in the investigation of the Philadelphia water supply, proposed by Dr. Hooker, special attention be directed to those districts which are affected with typhoid fever. In Germantown, in the Twenty-second Ward, typhoid fever has been unusually prevalent for more than a year past, but during the last three months it has increased to such an extent as to produce a general feeling of alarm and to call for a special investigation by the Board of Health. Unfortunately this investigation does not appear to have been as thorough and extended as the case demanded. It is believed that there have been in Germantown a larger number of cases of typhoid than in any other section of the city, except, perhaps, the district of Kensington, where this disease has prevailed for many years. By very many residents the disease is attributed to the Schuylkill water, which is supplied to Germantown from Flat Rock Dam, the uppermost of the pumping stations, by the Philadelphia Water Department. Prof. A. R. Leeds, of Stevens Institute, Hoboken, N. J., has stated in positive terms that the Schuylkill water has been the cause of typhoid fever in some cases. Very many residents of Germantown will not drink the river water unless it is boiled and filtered. There is, in consequence, a disposition to resort to well water instead of the river supply, a proceeding which is far more dangerous, for a large proportion of these wells, which are quite numerous, are undoubtedly contaminated with sewage.

A prominent physician, long a resident of Germantown, and who has had many of these typhoid cases, believes, on the other hand, that the disease cannot be attributed to the Schuylkill water.

Mr. Haines alluded to other causes to which the typhoid might be attributed, among which was the prevailing unsatisfactory condition of house drainage, especially in the older dwellings in Germantown, very many of which have not been arranged in accordance with the recent regulations of the Board of Health, not being properly trapped, and having no ventilating pipe to the soil pipe. Some of the houses built during the past few years are also believed to be in an unsafe sanitary condition, in consequence of improper or imperfect plumbing fixtures. The probability of a contaminated and adulterated milk supply being the cause of typhoid fever, was suggested by Dr. Tuttle.

Mr. Haines also alluded to the fact that Dr. Thos. M. Drown, of the Massachusetts Institute of Technology, has recently applied the Kjeldahl process for organic nitrogen to the determination of organic matter in water. The

result appears to warrant the belief that the process will be an important adjunct in water analysis.

Mr. Rowland suggested the determination of suspended matter as advisable.

In regard to the Kensington district Dr. Wahl referred to the extensive use of well water as the probable cause of much sickness.

Dr. Tuttle remarked on the advisability of analyzing the water of suspected wells.

The President called attention to a number of cases of typhoid fever which occurred in one family, and which were clearly traceable to contaminated well water and unsanitary conditions in the dwelling-house.

Dr. Samuel C. Hooker read a paper "On the Occurrence of Lapachic Acid in Bethabarra Wood," giving the results of an investigation undertaken in conjunction with Dr. Wm. H. Greene. The authors have unquestionably established the identity of the yellow principle of the Bethabarra wood with lapachic acid. A number of beautiful specimens were exhibited, both of the acid and of compounds prepared from it. One of the most interesting of these, lapachone, will be made the subject of further study, as the constitition which has been assigned to it is not in accordance with many new reactions observed. The results so far obtained point very strongly to the conclusion that lapachone is a derivative of naphto-furfuran and has the formula

$$C_{10}H_4 \left\{ \begin{array}{l} O_2 \\ CH_2 \\ O \end{array} \right. \!\!\! \begin{array}{l} \diagdown \\ \diagup \end{array} CH,C_2H_7$$

The opinion was also expressed that the compound prepared by Paternò, and considered by him to be brom-lapachic acid is in reality brom-lapachone having the formula

$$C_{10}H_4 \left\{ \begin{array}{l} O_2 \\ CH\ (Br) \\ O \end{array} \right. \!\!\! \begin{array}{l} \diagdown \\ \diagup \end{array} CH,C_2H_7$$

Dr. Smith and Mr. Frankel presented a paper on the electrolytic separation of mercury and copper, which was submitted for printing and distribution among the members, and was referred for publication.

Dr. Smith also stated that in the electrolysis of nickel and cobalt, in a solution containing potassium cyanide in excess, cobalt does not separate out, but whether these metals can be separated by this means remains to be seen.

Dr. Wahl showed some specimens of decorated glass in which the ornamentation was the result of coating a colored or flashed glass on one side with glue or gelatine, and then drying this in a current of air; the gelatine in drying contracts with sufficient force to tear away portions of the surface of the glass, thus producing striking and beautiful effects.

Adjourned. WM. C. DAY, *Secretary.*

ON THE OCCURRENCE OF LAPACHIC ACID IN BETHABARRA WOOD.

By WM. H. GREENE and SAMUEL C. HOOKER.

[*Read at the Meeting of the Chemical Section, April 16, 1889.*]

A few weeks ago we were asked by Mr. A. B. Shipley, of this city, a large importer of Bethabarra wood, to investigate the properties of a yellow substance with which the pores of the wood appear to be filled. So far as we know, the wood is used in this country for the manufacture of bows and fishing-rods only, for which purpose it is admirably adapted, on account of its great tenacity and remarkable elasticity.

We have been able to learn nothing of the botanical nature of the tree yielding the Bethabarra wood, which is said to be brought from the West Coast of Africa, but we believe that we may venture the opinion that it is a species of Lapacho. The latter is one of the finest ornaments of the sub-tropical hills and plains of South America. Its far spreading branches are in the spring covered with masses of flowers, red or yellow, according to the variety, so dense that the rays of the sun cannot penetrate them. Its wood is very hard, susceptible of a fine polish, and resists indefinitely the action of moisture.

The considerable cost of the wood made it desirable that, if possible, some use should be found for the refuse.

A few preliminary experiments with the extracted substance showed us that it contained a compound of much scientific interest, and for this reason we felt justified in undertaking the research, independently of any pecuniary result with which we were not concerned.

On referring to the literature of the subject, we found a paper entitled "Preliminary Notice of a New Vegetable Coloring Matter," published by Samuel P. Sadtler and William L. Rowland in December, 1880,* concerning the principle of the Bethabarra wood. Aside from analyses,

* *Amer. Chem. Jour.*, **3**, 22.

this paper throws but little light on the constitution and properties of the substance, dealing mainly with a comparison of the color reactions of the Bethabarra principle with crysophanic acid, santalin, hæmatoxylin and brasilin. The analyses of the authors left them undecided between the formulæ $C_{28}H_{29}O_5$ and $C_{22}H_{23}O_4$, and they conclude their paper with a suggestion that a close relationship exists between the Bethabarra principle and crysophanic acid and hæmatoxylin.

The Bethabarra wood used in our investigation was mainly in the form of sawdust. This was extracted in quantities of about five kilogrammes at a time by percolation with a cold one per cent. solution of crystallized sodium carbonate; the solution was allowed to remain in contact with the wood for several hours, and then drawn off, and the operation was repeated three or four times until the intensity of the deep red color of the extract was much diminished. The liquid was then treated with an excess of hydrochloric acid, and the precipitate allowed to settle, the excess of acid being necessary to insure the rapid separation of the precipitate. The clear liquid was then siphoned off, and the precipitate collected on a filter and dried.

This extract consists of the crystalline principle of the wood, accompanied by a resin, and as both are readily soluble in alcohol, this is not a desirable agent for the first crystallization as recommended by Sadtler and Rowland. On the other hand, we found the resin to be practically insoluble in ether, which freely dissolves the crystalline substance. The dry substance was broken up and shaken with ether in a closed flask; the addition of a few drops of water causes the resin to agglomerate and adhere to the walls of the flask; the ethereal solution could then be poured off without filtration. This operation was repeated with fresh ether; the ether distilled off, and the crystalline mass obtained was thrown on a filter and washed with a little alcohol at the pump. In this way the substance was obtained in a nearly pure condition, one recrystallization from alcohol yielding an absolutely pure product equal in quantity to at least 0·6 per cent. of the wood employed.

After a brief examination of our substance, we were struck by the remarkable similarity of its properties with those of taiguic acid,* which will be found described in Gmelin's Hand-Book, xvi, 521, and which has been shown by Paternò † to be identical with the greenhartin of Stein ‡ and with the lapachic acid of Siewert.§ Under the latter name, this substance has been the subject of an admirable research by E. Paternò,|| who from a series of concordant analyses deduced the formula $C^{15}H^{14}O^{3}$, and was able to assign to it with great probability the constitution of an amylene-oxynaphthaquinone.

$$C_{10}H_4\begin{cases}CH = CH - CH\,(CH_3)_2\\ O\\ OH\end{cases}$$

A close examination of the Bethabarra principle established its complete and unquestionable identity with lapachic acid. Its fusing point is 139°·5–140°·5; that of lapachic acid, as given by Paternò, is 138°.

We have prepared a number of characteristic salts. That of ammonia is unstable, losing ammonia with great readiness; a dilute solution of this salt deposits crystals of the acid when evaporated, as observed by Paternò with the ammonium compound of lapachic acid.

The silver salt is obtained as a bright red amorphous powder; on analysis we obtained the following figures:—

I.	0·2594 gr.	gave	0·0795 gr.	silver.
II.	0·2674 "	"	0·0830 "	"

	Found.		Calculated for
	I.	*II.*	$C^{15}H^{13}O^{3}Ag$.
Ag	30·65 per cent.	31·04 per cent.	30·95 per cent.

Mean of analyses by Paternò, 30·87 per cent. Ag. Analyses I and II were of compounds prepared separately.

* *Comptes rendus*, **46**, 1,152.

† *Gaz. Chim. Ital.*, 1879, **9**, 505.

‡ *Jour. prak. Chemie*, **99**, 1.

§ *La République Argentine*, par R. Napp, aidé de plusieurs collaborateurs. Ouvrage écrit par ordre du Comité central Argentin pour l'Exposition de Philadelphia. Buenos Ayres, 1876.

|| *Gaz. Chim. Ital.*, **12**, 337–392

By reducing agents the Bethabarra principle is converted with great facility into a white crystalline substance, which rapidly absorbs oxygen from the air, being reconverted into the original compound. This also characterizes lapachic acid.

By the action of concentrated sulphuric acid we have obtained a beautiful orange-red, quinone-like, crystalline substance, fusible at 155°–156° and identical with lapachone.* Concentrated nitric acid in the cold gives rise to the same substance, as shown by Paternò.

As the unexpectedly rapid result of our research has left us sufficient material to extend our investigations, and as the constitution assigned by Paternò to lapachone is not in accordance with some reactions which we have observed, we purpose to make this compound the subject of further study.

PHILADELPHIA, 10th April, 1889.

ON THE PRESENT CONDITION OF THE PHILADELPHIA WATER SUPPLY. FIRST MONTHLY REPORT

By SAMUEL C. HOOKER, Ph.D.

[*Read at the Stated Meeting of the Chemical Section, April 16, 1889.*]

Many considerations have induced me to undertake a systematic and frequent chemical examination of the water supplied to this city, and at the outset it would seem desirable that I should briefly enumerate some of the principal reasons for the investigation, and mention some of the beneficial results which it is to be hoped may arise from it. In approaching this question of the water supply of Philadelphia, which has given rise to so much discussion and difference of opinion, I desire it to be understood that I am primarily seeking for information, and that I wish to ascertain as nearly as possible the condition of the water at *all* times. We hear occasionally when the water is bad, but we

* Paternò, *loc. cit.*, 372.

do not hear when it is good. We should be acquainted with the good as well as with the bad aspect of the case, and deal with the question in a fair and unprejudiced manner. With the advantages offered by the large subsiding basin in the East Park, and with increased care in the prevention of the access of foul matter to the Schuylkill River, we should ask ourselves whether the condition of the water has so improved as to render it generally good, and to leave the times at which it may be seriously open to suspicion so few and far between as to make them of comparatively small importance. This is a question which can only be answered by a thorough and systematic examination such as I have commenced. Isolated analyses of samples purposely taken at times when everything conspires to make the water unusually bad, are of comparatively small value. Indeed, the information they give is such as to be positively misleading and to urge the belief that the water is at all times far worse than is really the case.

At the time my investigations were commenced the water was not systematically analyzed at regular and frequent intervals, and such analyses as were fitfully made, were not accessible to the public. The last published reports of the Water Department and also of the Health Department do not contain a single analysis, a fact which speaks more strongly than any other for the needs of such work as I have undertaken. The very unfavorable opinion to which—rightly or wrongly—some of the best known experts who have examined into the matter have come, regarding the condition of the Schuylkill River in the past, renders it highly desirable that the water supplied to the city should at all times be under chemical supervision. The interests of the public demand it. In the case of a river which is liable to pollution, it is obvious that circumstances may arise to make the water at times more than ordinarily dangerous. By frequent chemical examinations such a condition of the water would be detected at once, the public could be warned of it, and steps taken to find and remove, or at least mitigate the cause of the trouble. It is, therefore, extremely desirable that the water should be very frequently

analyzed, both for the information and protection of the public.

Aside from throwing some light on the question of wholesomeness, it is to be hoped that the present investigation may arouse public interest, with the view to pushing forward such improvements as will be instrumental in securing a *cleaner* supply.

In the face of such difference of opinion as exists regarding the wholesomeness of the Schuylkill, it is certainly satisfactory to find one point upon which all are agreed, and which does not admit of contradiction or argument. For whether the water be wholesome or unwholesome, whether it be charged with sewage or free from such contamination, whether it be loaded with or free from disease, it cannot be denied that the muddy condition of the water very frequently supplied to certain sections of the city, and at intervals to others, is a great and ever increasing disgrace to the city of Philadelphia.

The samples of water for analysis are drawn every Friday morning from six sections of the city, which have been carefully selected, so as to include all the probable variations in condition which the supply may simultaneously present at different portions of the city. This refers only to the water from the Schuylkill.

The samples are collected in the following neighborhoods:

(1) Sixteenth and Locust.
(2) Front and Bainbridge.
(3) Forty-fourth and Chestnut.
(4) Beach and Vienna.
(5) Twentieth and Columbia Avenue.
(6) 4000 Germantown Avenue.

(1) The first of these localities is usually supplied from the Spring Garden pumping station through the Corinthian Avenue basin. It may also be supplied from the Fairmount, Spring Garden and East Park reservoirs. The water at this point represents the supply of the district between Vine and South Streets.

(2) The city below South Street is fed by the Fairmount pumping station through the Fairmount reservoir. This part of the city may also be supplied in case of necessity from the Corinthian Avenue basin.

(3) The sample drawn at Forty-fourth and Chestnut is representative of the whole of West Philadelphia. The water is pumped at the Belmont Station and supplied through the Belmont reservoir.

(4) Kensington, in which Beach and Vienna is situated, formerly received its supply from the Delaware. Since the middle of September, 1888, Schuylkill water has been fed to this district. In future it is proposed to pump Delaware water only in the case of emergency.

(5) The water drawn at Twentieth and Columbia Avenue represents that of the whole of the Northwestern portion of the city. This district, which is bounded on the north by Allegheny Avenue, on the south by Vine Street, and on the east by Broad Street, is supplied by direct pumpage from the Spring Garden works.

(6) The Twenty-second and part of the Twenty-eighth Wards are supplied from the Mt. Airy reservoir, which is fed from the Roxborough Station. The water drawn at Germantown Avenue represents this district.

By thus collecting the water as actually supplied to the city instead of taking it directly from the river or the reservoirs, not only are fairer samples obtained, but the water should be at its best, having had the advantage of passing through the subsiding basins.

It is to be hoped that as improvements are made a careful study of these reports will lead to those sections of the city which are at present worst off being first considered.

Although a lengthy discussion of the methods of analysis is unnecessary, it may be well briefly to mention the processes employed.

The determinations of albumenoid and free ammonia were made in all essential particulars as recommended by Wanklyn. Duplicate analyses, occasionally made to test the accuracy of the results, gave figures so closely cor-

responding to the first determinations as to leave little to be desired.

The chlorine was estimated by the well-known volumetric process. The greatest possible care was taken with these determinations, as very slight variations appear of considerable importance. Duplicate determinations were made in every case and the mean of at least two experiments taken. The nitrates were determined by the carbazol process, devised by myself, and already described in detail to the Section.

The following table gives the results obtained:

ANALYSIS OF THE PHILADELPHIA WATER SUPPLY.

Kensington, Beach and Vienna.

Date. 1889.	*Chlorine.*	*Free Ammonia.*	*Albumenoid Ammonia.*	*Nitrogen of Nitrates.*
March 15th, ...	·32	·0005	·0055	·14
" 22d, ...	·32	·0005	·0050	·14
" 29th, ...	·38	·0005	·0065	·12
[April 5th, ...	·51	·0075	·0190	·07]
" 12th, ...	·34	·0005	·0070	·10
Average, omitting the sample of April 5th, as from the Delaware,	·34	·0005	·0060	·125

West Philadelphia.

Date. 1889.	*Chlorine.*	*Free Ammonia.*	*Albumenoid Ammonia.*	*Nitrogen of Nitrates.*
March 15th, ...	·30	·0025	·0045	·14
" 22d, ...	·15	·0020	·0050	·14
" 29th, ...	·27	.0025	·0070	·11
April 5th, ...	·27	·0020	·0075	·10
" 12th, ...	·31	·0010	·0065	·10
Average, ...	·26	·0020	·0061	·118

Sixteenth and Locust.

Date. 1889.	*Chlorine.*	*Free Ammonia.*	*Albumenoid Ammonia.*	*Nitrogen of Nitrates.*
March 15th, ...	·27	·0000	·0105	·14
" 22d, ...	·24	·0000	·0070	·14
" 29th, ...	·35	·0015	·0075	·12
April 5th, ...	·26	·0015	·0080	·11
" 12th, ...	·35	·0010	·0085	·10
Average, ...	·29	·0008	·0083	·122

Front and Bainbridge.

Date. 1889.	*Chlorine.*	*Free Ammonia.*	*Albumenoid Ammonia.*	*Nitrogen of Nitrates.*
March 15th, Sample not forwarded.				
March 22d, ...	·32	·0005	·0075	·14
" 29th, ...	·36	·0005	·0055	·12
April 5th, ...	·28	·0010	·0070	·10
" 12th, ...	·35	·0010	·0090	·09
Average, ...	.32	·0007	·0072	·112

Twentieth and Columbia Avenue.

March 15th, ...	·30	·0000	·0070	·13
" 22d, ...	·35	·0005	·0100	·14
" 29th, ...	·37	·0020	·0085	·11
April 5th, ...	·26	·0015	·0140	11
" 12th, Demijohn broken in transit.				
Average, ...	·32	·0010	·0098	·122

4000 Germantown Avenue.

March 15th, Sample not on time.				
" 22d, ...	·25	·0005	·0110	·12
" 29th, ...	·30	·0005	·0165	·11
April 5th, ...	·26	·0015	0125	·10
" 12th, Sample not on time.				
Average, ...	·27	·0008	·0133	·110

All the above results are expressed in parts per 100,000.

It will be apparent to any one at all familiar with the subject, that the worst feature of these analyses lies in the comparatively large amount of nitrates. Apart from this, the condition of all the samples examined from the Schuylkill—twenty-four in number—is very satisfactory, and if maintained throughout the year, would render any serious anxiety as to the wholesomeness of the supply quite unnecessary. It is certainly gratifying to find the condition of the water so uninterruptedly satisfactory during a whole month, and so much better than one could have fairly expected from the pessimistic reports which have recently from time to time been published in the newspapers. It will be understood that I am at present speaking of the

quality of the water without reference to its muddiness. With regard to this latter particular, the condition of all the water could not by any means be said to be satisfactory.

It will be observed that the sample drawn at Beach and Vienna on April 5th, was vastly inferior to the remaining samples collected at the same locality on other days, and also to the other samples collected at other points on the same date. Although I had information that Kensington was drawing its water from the Schuylkill I could not believe that this was really the case at the time that this particular sample was drawn. I consequently made a personal visit to the Kensington Water Works, on April 11th, to clear up the matter, and was gratified to find that my surmise was correct. The pump at the works was drawing water from the Delaware at that date, and had been doing so since April 3d, on account of a breakdown at the Spring Garden Station.

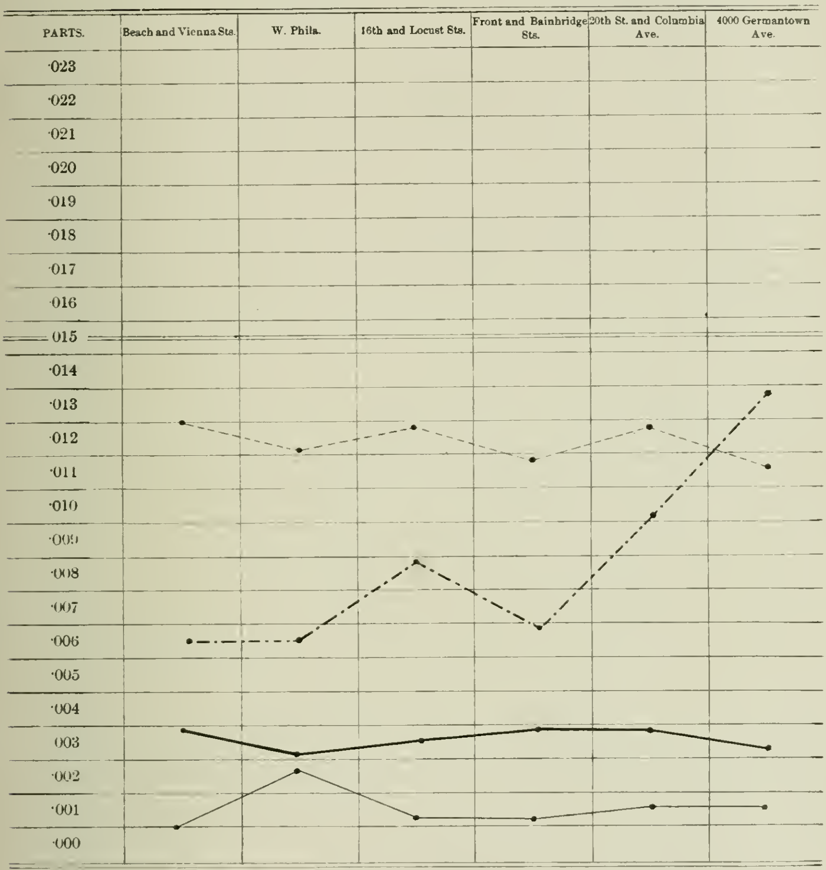
Pumping from the Delaware, at the Kensington Works, still continues at the present date, but the Lehigh basin, into which the water is forced, is apt to be low towards the evening, at which time the overflow from the Spring Garden basin is permitted to flow into it. Samples collected in the early morning may, therefore, consist almost entirely of Schuylkill water. This explains the good condition of the water from this district on April 12th, and its very great similarity to the samples drawn previous to April 3d.

From an examination of the table it will be observed that on the whole the quality of the water in each locality has been very uniform doing the past month. There is, however, a marked difference in some respects in the water from the different localities. For instance, the free ammonia is almost constantly higher in West Philadelphia than in other portions of the city, and similarly the albumenoid ammonia is higher in Germantown than elsewhere. Should these differences be maintained, they will be fully considered in detail in subsequent reports.

My observations so far show that the albumenoid ammonia is greater in the turbid samples, even after filtration through paper, than in the clearer ones, or in other words that the

DIAGRAM SHOWING THE AVERAGE RELATIVE CONDITION OF THE WATER SUPPLY AT DIFFERENT POINTS OF THE CITY. March 15 to April 12, 1889.

(CONSTRUCTED FROM 24 ANALYSES.)



EXPLANATORY NOTES:

- - - - - - - - - - { Nitrogen of Nitrates in parts per 10,000. Representing, when in excess, animal matter, which by natural processes of purification has been rendered harmless.

—·—·—·— { Albuminoid Ammonia in parts per 100,000. Representing, when in excess, nitrogenous organic matter of the most dangerous type.

——— { Chlorine in parts per 1,000. Representing, when in excess, present or past sewage contamination.

——— { Free Ammonia in parts per 100,000. Representing, when in excess, decaying organic matter.

Provided that the two lower curves do not vary much in height from those given, the condition of the water may be regarded as satisfactory, so long as the two upper curves remain below the double line through ·015.

It will be understood that the smaller the quantity of the substances indicated by the above curves, the more satisfactory the condition of the water. In other words, the water is most satisfactory with regard to each particular substance, at the lowest point of each curve.

albumenoid ammonia is in some degree proportional to the turbidity.

This is well shown in the following table:

Average order of turbidity for the month. The water from the first locality being the best, i. e., the brightest.	*Average of albumenoid ammonia for the same period.*
1. Kensington,	·0060
2. West Philadelphia,	·0061
3. Sixteenth and Locust,	·0083
4. Front and Bainbridge,	·0072
5. Columbia Avenue,	·0098
6. Germantown,	·0133

The full meaning of this, which has, I believe, considerable bearing on the quality of the Germantown water as compared with that of other localities, will be considered in a subsequent report when the data collected have become somewhat larger.

As it is intended that the results of these analyses may clearly and readily be understood by those who are not chemists, a diagram is appended, which it is believed will be made thoroughly intelligible to all by the aid of the explanatory notes accompanying it.

SCIENTIFIC NOTES AND COMMENTS.

MECHANICAL ENGINEERING.

Trials of Motors for Electric Lighting.—In September, 1888, Dr. John Hopkinson, Mr. Beauchamp Tower and Prof. Alexander B. W. Kennedy carried out a series of motor trials for the Society of Arts (*Journal of the Society of Arts*).

The motors tested were a Crossley (Otto) nine nominal horse-power, a Griffin eight nominal horse power, and an Atkinson six nominal horse-power, all gas engines, and a Davey-Paxman compound portable steam engine of eight nominal horse-power. The judges awarded a gold medal to the Paxman and to the Atkinson engines, as they were each the sole representatives of a class, and had each given exceptionally good results. In the cases of the other engines, the Crossley had the advantage as to economy of gas and lubricant, and the Griffin in respect to regularity of speed, and a gold medal was awarded each.

The trials consisted of an efficiency test of six hours duration for each engine, a three hours' run at half power, a test running light, and other tests

made at the request of the exhibitors, under conditions different from the competitive conditions.

The methods of the trials were generally as follows: The gas used in the engine and for ignition was measured separately, wet meters being used, and readings taken every quarter of an hour. The pressure and temperature of the gas were measured in the meter, and samples of the gas taken for analysis. Indicator diagrams were taken every quarter of an hour. The springs were tested and the errors found to be very small. Rope brakes were used for absorbing the power. The water fed to cylinder jackets was metered and its temperature taken. The number of revolutions were taken from a continuous counter, read every fifteen minutes simultaneously with the reading of the gas meters. The number of explosions was determined.

The steam engine was tested in practically the same way, the coal burned and water evaporated were weighed, the indicator cards and revolutions taken as in the gas engine trials. The power was absorbed by a rope friction brake, but, instead of trusting to the air cooling the wheel, water was allowed to drip into the trough inside the rim and evaporate out. The cylinders were fitted with jackets, but the exhibitor elected to run without them. In all cases the quantity of lubricator fed to the cylinder was measured. The following are the principal dimensions of the engines tested:

Crossley.—9·5 inches diameter cylinder, 18 inches stroke. One fly wheel 5 feet 5½ inches diameter, 9 inches face, weighing 1,652 pounds. Fitted with countershaft for running dynamos.

Griffin.—9·02 inches diameter cylinder, 14 inches stroke. Two fly-wheels 60·1 inches diameter, 7·5 inches face, each weighing 1,144 pounds. The piston-rod 1·75 inches diameter.

Atkinson.—9·5 inches diameter cylinder, suction stroke 6·33 inches, compression 5·03 inches, working 11·13 inches, and the exhaust stroke 12·43 inches. Radius of crank, 12⅞ inches. Two fly-wheels 69·3 inches diameter, 4·5 inches face, each weighing 1,462 pounds.

Paxman Portable.—Boiler of locomotive type. Engine, compound horizontal cylinders, 5·24 inches and 8·98 inches diameter by 14 inches stroke. One fly-wheel 62 inches diameter, 7⅜ inches face and weighing 910 pounds.

The following tables show the results of the full and half power trials. In estimating the gas per brake horse-power for the Crossley engine, the power to run the countershaft was omitted, and taking this into consideration gives 27·4 cubic feet of gas per net horse-power available for outside work. The results of the second trial with the steam engine are given here. As in the first one, some exhaust steam was returned to the feed-tank, and the amount could not be determined.

FULL POWER TRIALS.

	Atkinson.	Crossley.	Griffin.	Paxman.
Duration, hours,	6	6	6	6·27
Revolutions per minute,	131·1	160·1	198·1	137·35
Explosions " "	121·6	78·4	129·0	
Mean initial pressure, pounds,	166·0	196·9	132·3	H.P. 176·8
Mean effective pressure, pounds,	46·07	67·9	54·15	H.P. 54·98 L.P. 16·78
Indicated horse-power,	11·15	17·12	15·47	H.P. 11·30 L.P. 10·26 21·56
Brake load, net, pounds,	130·5	177·4	130·7	288·0
Brake horse-power,	9·48	14·74	12·51	18·95
Mechanical efficiency,	·85	·861	·809	·879
Gas per hour, main, cubic feet,	209·8	351·8	350·2	. . .
" " " ignition,	4·5	3·5	7·1	. . .
" " " total,	214·3	355·3	357·3	. . .
Gas per i. h. p., per hour, main,	18·82	20·55	22·64	. . .
" " " " " total,	19·22	20·76	23·10	. . .
Gas per b. h. p., per hour, main,	22·14	23·87	28·00	. . .
" " " " " total,	22·61	24·10	28·56	. . .
Water per hour, pounds,	680·	713·	1022·	. . .
Rise in temperature,	52°·2	128°·0	71°·8	. .
Horse-power in driving engine	1·67	2·38	2.96	2·61
Mean pressure during working stroke equivalent to work done in pumping stroke about, pounds,	1·00	2·19	2·40	. . .
Corresponding i. h. p.,	·26	·55	·69	. . .

HALF POWER TRIALS.

	Atkinson.	Crossley.	Griffin.	Paxman.
Duration, hours,	3	3	3	3·12
Revolutions per minute,	129·6	158·8	201·8	138·10
Explosions " "	69·1	41·1	82·6	. . .
Mean initial pressure,	166·5	196·2	135·1	H.P. 113·0
Mean effective pressure,	47·60	73·4	55·85	H.P. 33·25 L.P. 8·92
Indicated horse-power,	6·59	9·73	10·23	H.P. 6·85 L.P. 5·47 12·32
Brake load, net,	66·0	89·9	64·67	147·6
Brake horse-power,	4·74	7·41	6·30	9·76
Mechanical efficiency,	·719	·762	·616	·792
Gas per hour, main,	127·1	202·6	228·7	. . .
" " " ignition,	5·9	3·2	5·8	. . .
" " " total,	133·0	205·8	234·5	. . .
Gas per i. h. p., per hour, main,	19·29	20·8	22·35	. . .
" " " " " total,	20·18	21·2	22·92	. . .
Gas per brake horse-power, main,	26·80	27·34	36·30	. . .
" " " " total,	28·10	27·77	37·20	. . .
Water per hour, in pounds,	260·	480·	616·6	. . .
Rise in temperature,	67·8	102·3	71·31	. . .
Horse-power in driving engine,	1·85	2·31	3·93	2·56

BOILER.

	Full Power.	Half Power.
Boiler pressure, absolute,	202·78	134·9
Temperature, steam,	382·9	350·1
Pounds of feed water, per hour,	447·1	392·2
" " " i. h. p.,	20·74	26·72
" " " b. h. p.,	23·59	33·73
Mean temperature, feed	63°·0	69°·9
Temperature of gases, Fahr.,	304°·4	369°·1
Coal per hour*, pounds,	40·70	27·25
" " " per i. h. p.,	1·89	2·21
" " " " b. h. p.,	2·15	2·79
Pounds water per pound coal,	10·99	12·08
" " from and at 212°,	11·71	12·76

In the reports of the trials, tables are given showing approximately the percentage of the available heat turned into work, rejected in jacket water, and rejected in the exhaust, radiation, etc. During the full power trials, in the Atkinson engine, of 13,280 heat units available per explosion, 25·5 per cent. was converted into work and twenty-seven per cent. rejected in the jacket water. In the Crossley test of 34,040 heat units available 22·1 per cent. was converted into work and 43·2 per cent. was rejected in the jacket water. In the Griffin trial of 20,650 available heat units 21·1 per cent. was converted into work and 35·2 per cent. rejected in the jacket water. In the steam engine of 577,900 heat units available per hour 9·6 per cent. was converted into work. In the boiler, during the full power trial, of 577,900 heat units available, 79·65 per cent. was expended in heating and evaporating the water, 7·05 per cent. in raising the temperature of the furnace gases, 8·85 per cent. was lost by radiation, 2·68 per cent. by imperfect combustion, ·10 per cent. in evaporating the moisture in the coal and 1·67 per cent. was unaccounted for.

It is to be regretted that there were not more engines entered for trial. The work done in carrying out these trials is of the very best character, and the results are a considerable addition to our stock of knowledge.

The report contains many other data in addition to that given above and is well worth studying. H. W. S.

BOOK NOTICES.

FRICTION-BRAKE DYNAMOMETERS.—William Worby Beaumont, M. Inst. C. E. With an Abstract of the Discussion on the Paper. From Minutes of Proceedings of the Institution of Civil Engineers. Vol. xcv. Session 1888–89. London.

The paper is a description of the various forms of friction brakes modelled on the Prony brake, and treats of the inaccuracies of the methods of measuring and the reliability of the results obtained from them.

* Calorific value, 14,200 thermal units per pound, no reduction being made from the hydrogen for the oxygen present.

In the original Prony brake, the author states that for measuring the power of a motor at uniform speed and constant load, the inaccuracy of its indications may be very small and often insignificant. The necessity of changing the tension on the brake strap to maintain the load constant, makes a self-regulating dynamometer greatly to be desired.

The compensating brake of M. Deprez, suitable for small powers, is described. In this the compensation takes place slowly and adjustments have frequently to be made.

A simple form of self adjusting dynamometer, made by Mr. J. Imray, is described and several forms of brakes, with Appold's compensating lever, are described. Numerous other special forms are treated of in the paper and in the discussion following it.

An attempt is made to determine the proportion of brakes from several successful examples, but beyond giving the dimensions of brakes in use is of no especial importance.

In the paper and discussion numerous rope brakes were spoken of, which for ease of construction and use will compare favorably with the more elaborate forms spoken of. Professor Kennedy, one of the conductors of the motor trials for the Society of Arts, described the apparatus used in these tests.

A hemp rope or a couple of ropes, one and three-quarter-inch circumference, passing around the wheel once, was weighted at one end and attached to a spring balance at the other. A wheel, five feet in diameter, seven inches face, weighing 910 pounds, running at 140 revolutions per minute, took nineteen and one-half brake horse-power without trouble. Water dripped into the trough on the inside of the rim and evaporated out.

The entire paper is a fair account of the various devices in use for absorbing power, and in the discussion there is considerable difference of opinion as to their relative advantages. H. W. S.

A Treatise on Hydraulics. By Mansfield Merriman. 8vo. John Wiley & Sons, New York, Publishers.

This timely production adds another to the many works on this important subject, and yet there is room. The reputation of this well-known author for thoroughness will at once commend this book to the student as a valuable accession. A brief review of its contents shows that it is prepared with reference to modern requirements. They cover such topics as hydrostatics; theoretical hydraulics; flow through orifices, over weirs, through tubes, in pipes, conduits, canals and rivers; measurement of water-power; dynamic pressure of flowing water; hydraulic motors and naval hydromechanics; all of which are included in 381 pages of attractive typography. The demonstrations are treated, in general, analytically and in some instances with the aid of calculus, so that the book is limited to those familiar with the pure mathematics, although there are many deductions and general principles of use to the practical hydraulician.

In a treatment so condensed of so extended a subject matter, many

important sub-divisions must necessarily have been greatly abridged, as, *e.g.*, those relating to the stability of flotation, back-water, dams, tidal energy, and waves, some of which acquire great practical importance to the maritime and hydraulic engineer.

The question of the position of the metacentre is of much more frequent application in engineering construction than in the construction of ships, and acquires importance in the various form of caissons for sub-marine foundations built on shore and floated to their proposed sites. The entire question of masonry dams is disposed of by giving the general equation of equilibrium, with an example, all included in less than two pages.

Usually but one problem is required to illustrate a principle, and that without the answer. We believe it better to state the result, that the student may be able to check his work, and so increase his confidence in his ability to solve similar cases.

In the numerous references which are stated in the foot-notes, it would also appear to be more satisfactory, to those wishing to consult the authorities, to have a specific address, either of the publisher or of a depository, where the work may be found. Thus we find, "Smith's Hydraulics, p. 176," "Del Moto dei Gravi (Firenz, 1644)," etc.

The most important omission, however, is the absence of a topical index, arranged alphabetically. This is but poorly supplied by the table of contents, moreover we must take exception to the statement made on the closing page, that "upon the ocean, waves move in the same direction as the wind, but along shore it is observed that they move normally towards it, whatever may be the direction in which the wind is blowing," as being contrary to the fact, since the well-nigh universally received opinion as to the motion of waves (breakers) on shore is curvilinear, being retarded at the shore line, and breaking at a prevalent if not a permanent angle, which is determined rather by the form of the fore-shore than by the direction of the wind. This is an important phenomenon, and accounts for the travelling of the beaches and inlets in a prevalent direction, and furnishes the key to the solution of many harbor problems.

Space will not permit us to call attention to the many good features of the work, which will commend itself to instructors and students alike for the clearness and logic of its demonstrations. H.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Agricultural Experiment Station. Auburn, Ala. Bulletin No. 4.
From the Station.

Adjutant-General, New Jersey. General Orders Nos. 4 and 5.
From the Adjutant-General.

Bay City, Mich., Seventeenth Annual Report of the Superintendent of the Water Works for 1888.
From the Superintendent.

Board of Directors of City Trusts. Nineteenth Annual Report for 1888.
From the Board.

Board of Gas Commissioners. Massachusetts. Fourth Annual Report.
From the Board.

Brown, Harold P. The Comparative Danger to Life of the Alternating and Continuous Electrical Currents. From the Author.

Buffalo, N. Y. Twentieth Annual Report of the Water Works for 1888.
From the Water Commissioners.

Bureau of Education U. S. Circular of Information. No. 6. 1888.
From the Bureau.

Canadian Society of Civil Engineers. Charter, By-Laws and List of Members.
From the Society.

Commerce. An Act to Regulate.
From the Inter-State Commerce Commission.

Concord, N. H. Seventeenth Annual Report of the Board of Water Commissioners for 1888. From the Commissioners.

Connecticut Agricultural Experiment Station. Annual Report for 1888. Part 2. From the Station.

Connecticut Board of Agriculture. Eighth Annual Report of the Secretary, 1874–75. From the Secretary.

Connecticut State Agricultural Society. Transactions for 1854.
From the Secretary of the State Board of Agriculture.

Connecticut State Board of Health. Eleventh Annual Report.
From the Board.

Dairy Commissioner, State of New Jersey. Annual Report for 1888.
From the Officer.

Delights of Coaching, by an Old Whip. From Murphy & Co.

Department of Public Works, Chicago. Thirteenth Annual Report.
From the Commissioner of Public Works.

Electricity. Works relating to.
Abernathy. Commercial and Railway Telegraphy.
Aglave and Boulard. The Electric Light.
Atkinson. Elements of Static Electricity.
Atkinson. Gauot's Physics.
Ayrton. Practical Electricity.
Badt. Dynamo Tender's Hand-Book.
Benjamin. Age of Electricity.
Bottone. The Dynamo.
Bottone. Electrical Instrument Making.
Culley. Hand-Book of Practical Telegraphy.
Cumming. Theory of Electricity.
Day. Electric Light Arithmetic.
Day. Electrical Measurement.
DuMoncel. Electricity as a Motive Power.
DuMoncel. Electro-Magnets.
Dyer. Induction Coils.
Esson. Magneto- and Dynamo-Electric Machines.

Electricity. Works relating to.

Fiske. Electricity and Electrical Engineering.
Gladstone and Tribe. Chemistry of the Secondary Batteries.
Gordon. Treatise on Electric Lighting.
Hamilton. All Matter Tends to Rotation.
Hedges. Precautions on Introducing the Electric Light.
Hering. Dynamo Electric Machinery.
Holmes. Practical Electric Lighting.
Hospitalier. Domestic Electricity.
Hospitalier. Modern Applications of Electricity.
Kapp. Electric Transmission of Energy.
Kempe. Hand-Book of Electrical Testing.
Kennedy. Electrical Distribution.
Kimball. The Dynamo.
Levander. Solutions of Questions on Electricity and Magnetism.
Lockwood. Practical Information for Telephonists.
Maier. Arc and Glow Lamps.
Martin and Wetzler. The Electric Motor.
Maxwell. Electricity and Magnetism.
Morton and Anderson. Electric Lighting.
Munro and Jamieson's Pocket-book of Rules.
Niaudet. Electric Batteries.
Noad. Text-Book of Electricity.
Planté. Storage of Electrical Energy.
Prescott. Dynamo Electricity.
Stephen. Wrinkles in Electric Lighting.
Swinburne. Electrical Units.
Thompson. Dynamo Electric Machinery.
Thompson. Elementary Lessons in Electricity.
Thurston. Stationary Steam Engine.
Urbanitzky. Electricity in the Service of Man.
Urquhart. Electric Light.
Watson and Burbury. Mathematical Theory of Electricity and Magnetism.
Walker. Practical Dynamo Building.

From the Electrical Section.

Ewing, Thomas. Address at the Centennial Celebration at Marietta, O. July, 1888. From the Author.

Germanischer Lloyd. Internationales Register. 1889. Zweiter Nachtrag. From Lars Westergaard & Co.

Hydrographic Office. Pilot Chart of the North Atlantic Ocean. April, 1889. From the Philadelphia Branch.

Institution of Civil Engineers. Minutes of Proceedings. Vol. 95. From the Institution.

Inter-State Commerce Commission. Second Annual Report. From the Commission.

Iowa Railroad Commissioners. Third to Eleventh Annual Reports for Years ending June 30, 1880, to 1888.
Map and Profiles of the Iowa Railroads. 1881. From the Commissioners.

Jewish Hospital Association. Twenty-Fourth Annual Report.
From the Secretary of the Association.

Kansas Board of Railroad Commissioners. Sixth Annual Report for 1888.
From the Commissioners.

Kansas Public Documents. 1887–8. Vols. 1 and 2.
From H. J. Dennis, State Librarian.

Kansas State Board of Agriculture. Sixth Biennial Report.
Proceedings of the Eighteenth Annual Meeting. From the Board.

Locomotive, The. New Series. Vol. 9.
From the President Hartford Steam Boiler Inspection and Insurance Co.

Macon, Ga. Seventh Annual Report of the Board of Health for 1888.
From the Board.

Manchester Literary and Philosophical Society Memoirs and Proceedings. Fourth Series, Vol. 1. From the Society.

Manchester, N. H. Annual Reports of the Board of Water Commissioners for 1873 and 1887–88. From the Board.

Massachusetts Board of Education. Fifty-second Annual Report.
From the State Library.

Massachusetts Board of Railroad Commissioners. Twentieth Annual Report. From the Board.

Massachusetts Manual for the General Court. 1889.
From the Secretary of State.

Massachusetts State Board of Health. Report upon the Sewerage of the Mystic and Charles River Valleys. From the Board.

Massachusetts State Agricultural Experiment Station. Bulletin No. 32.
From the Station.

Medford, Mass. Eleventh and Nineteenth Reports of the Water Commissioners, etc., for the years 1880 and 1888.
From the Commissioners.

Mercantile Library Association, San Francisco. Thirty-sixth Annual Report.
From the Association.

Mercantile Library Company, Philadelphia. Sixty-sixth Annual Report.
From the Company.

Meteorological Department, Government of India. Charts of the Arabian Sea.
Indian Meteorological Memoirs. Vol. 3, Parts 3 and 4. Vol. 4, Part 5.
Report of the Administration. 1887–8.
Meteorological Observations Recorded at Six Stations in India. August and September, 1888. From the Department.

Michigan State Board of Agriculture. Twenty-sixth and Twenty-seventh Annual Reports, from October, 1886, to June 30, 1888.
From the Board.

Michigan State Board of Health. Abstract of Proceedings. February, 1889. Restricting communicable diseases. From the Board.

Minnesota. Annual Reports of the Board of Regents of the University of Minnesota for 1874, 1877 and 1878, and First to Third Biennial Reports for 1879–80 to 1883–84.
Minneapolis, Minn. Annual Reports of the Board of Water Commissioners for Year ending March 1, 1882, to 1887, and Annual Report of the City Water Works Department for the Year ending March 1, 1888.
From the Registrar.
National Water Works Company of New York, at Kansas City, Mo. Revised Water Rates, Rules and Regulations, etc.
From the Superintendent.
New Brunswick, N. J. Sixteenth Annual Report of the Water Commissioners. 1888. From the Commissioners.
New Hampshire. Annual Reports. 1888. Vols. 1 and 2.
From the Secretary of State.
New Jersey. General Index to the Documents relating to the Colonial History of the State. From the State Librarian.
New Jersey State Board of Health. Twelfth Annual Report.
From the Board.
New London, Conn. Annual Reports of the Water Commissioners, Fifteenth (two copies), Sixteenth and Seventeenth, for 1886, 1887 and 1888.
From the Commissioners.
Newton, Mass. Annual Report of the Overseers of the Poor for 1888.
From the Overseers.
New York State Museum of Natural History. Annual Reports, 1886 and 1887. Bulletins Nos. 2 to 6 inclusive.
From the Secretary New York State Library.
Ohio Agricultural Experiment Station. December, 1888. From the Station.
Paris Exposition and Eiffel Tower. Lithograph.
From Latham, Alexander & Co.
Payne, F. F. Eskimo of Hudson's Straits. From the Author.
Royal Institution. London. List of Members. 1888. Proceedings. Vol. 12, Part 2. From the Institution.
Royal Irish Academy. Proceedings. Third Series, Vol. 1, No. 1.
Transactions. Vol. 29, Parts 3 and 4.
From the Academy.
Société des Ingenieurs Civils. Annuaire 1889. From the Society.
Springfield, Mass. Fifteenth Annual Report of the Board of Water Commissioners for 1888. From the Board.
State Department United States. Consular Report, January, 1889.
From the Department.
University of the State of New York. One-hundredth, one hundred and first and one hundred and second Regent's Reports.
From the Secretary New York State Library.
University of Wisconsin. Agricultural Experiment Station. Bulletin No. 18.
From the Station.
United States Fish Commission. Fisheries and Fishery Industries of the United States. Section 3 and 4. From the Commission.
U. S. Department of Agriculture. Botanical Division. Bulletin No. 9.
Report of the Statistician, No. 50.
Experiment Station. Bulletin No. 1.
From the Secretary of Agriculture.
Virginia. Twelfth Annual Report of the Railroad Commissioner. 1888.
From the Commissioner.
War Department. Official Army Register. January, 1889.
From the Department.
Wyman, Morrill. Memoir of Daniel Treadwell. From the Author.
Zalinski, E. L. Naval Uses of the Pneumatic Torpedo Gun.
From the Author.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, April 17, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1889.

JOSEPH M. WILSON, President, in the Chair.

Present, 162 members and thirty-four visitors.

Additions to membership during the past month, 104.

By direction of the Board of Managers, the Actuary presented the following report of the condition of the Elliott Cresson Medal Fund, prepared and submitted by Mr. FREDERICK FRALEY, trustee of the fund, viz:

NO. 1000 WALNUT STREET,
PHILADELPHIA, April 8, 1889.

DEAR SIR:—A short time ago Mr. Heyl, the Actuary of the FRANKLIN INSTITUTE, called on me and stated that the managers desired to have a statement of the present amount of the Elliott Cresson Medal Fund, and also whether it would not be advisable to have an additional trustee of the fund appointed, in place of Mr. John Wiegand, who died some years ago. It gives me great pleasure to comply with these requests.

The fund was created by Mr. Elliott Cresson in the year 1848, and the capital of endowment was a certificate for $1,000 in the loan of the Schuylkill Navigation Company of the year 1845. The loan was then considerably below par, and no interest was paid on it for several years, owing to the unfavorable state of the finances of the company, and the disastrous results of the great flood on the Schuylkill River in 1850. When the Schuylkill Navigation Company's affairs were adjusted in 1852, the original certificate of fund and the arrears of interest thereon was converted into a certificate of the loan of 1882 for $740, and ten shares of prefered stock of the par value of $500, thus making the nominal capital of the fund, $1,240. The interest and dividends received on this sum and the accumulation thereof have been sufficient to pay for the dies for the medals, and the medals struck and delivered to the INSTITUTE, and to leave a balance to the credit of the fund, April 1, 1889, of $3,943.11, which consists of a certificate of loan of the City of Philadelphia for $1,700, deposit in the Western Saving Fund of $1.973.96, and cash in my hands of $269.15. When the affairs of the Philadelphia and Reading Railroad were reorganized, in 1887, the loan and preferred stock of the Schuylkill Navigation Company belonging to the fund were deposited under the plan, and converted to the

new Reading securities, which were sold and produced $548.64. This sum I believe is more than the original $1,000 of Schuylkill Navigation loan was worth in the market when the fund was created.

The dies for the medals are at the United States Mint in Philadelphia, and all the medals have so far been struck there.

I find by reference to the trust deed that whenever a vacancy occurs by the death or resignation of a trustee, his place is to be filled by an election to be made by the FRANKLIN INSTITUTE, at a stated meeting after due notice. I had not read the deed for many years, or I should have called the attention of the INSTITUTE to this matter immediately after the death of Mr. Wiegand. You have a copy of the deed in the minute-book, and from it will see how the election of a new trustee is to be made.

With my best wishes for the welfare and prosperity of the INSTITUTE of which I have been a member for sixty-four years, I am,

Sincerely yours,

FREDERICK FRALEY.

To JOSEPH M. WILSON, ESQ.,
President FRANKLIN INSTITUTE.

The Secretary reported the resignation of Mr. MOSES G. WILDER as a member of the Committee on Science and the Arts. The resignation was accepted and Mr. JOHN E. CODMAN was elected to fill the vacancy.

The Special Committee to Increase Membership made a report of progress, and was continued.

The Actuary further reported a recommendation from the Board of Managers, that Prof. LEWIS M. HAUPT (civil engineer), Mr. CARL HERING (electrical engineer) and Mr. F. LYNWOOD GARRISON (metallurgist), members of the INSTITUTE, who had expressed their willingness to act as representatives and to report upon subjects within their respective specialties, be appointed as delegates to the International Exhibition in Paris.

The recommendation was approved and the President and Secretary were authorized to issue a suitable document attesting the fact over their signatures and the seal of the INSTITUTE.

Mr. WM. B. LE VAN read a paper on "High Railway Speeds," illustrating it with the aid of lantern slides. The subject embraced substantially a comparison of English and American locomotives and rolling stock. (Referred for publication.)

Capt. E. L. ZALINSKI, U. S. A., presented an oral communication, supplementing his remarks at the March meeting, by a description of the U. S. cruiser *Vesuvius*, with lantern illustrations.

The Secretary's report embraced a description, with illustrations, of the proposed suspension bridge over the Hudson at New York, designed by Mr. GUSTAV LINDENTHAL, and an abstract of the report of the Committee on Science and the Arts on OTIS C. WHITE'S "Adjustable Extension Movement in Ball and Socket Joints," of which invention a fine suite of specimens was exhibited.

Adjourned. WM. H. WAHL, *Secretary*.

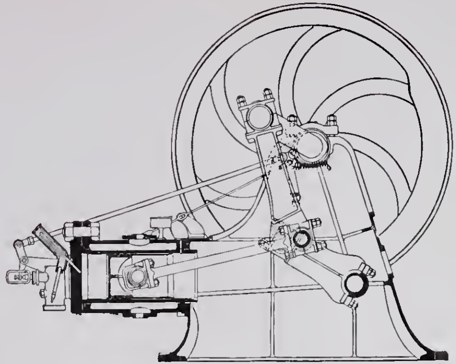


Fig. 1.—Atkinson's Gas Engine, 1886.

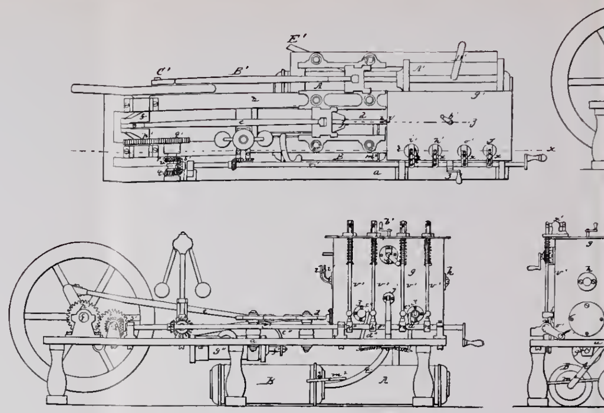


Fig. 7.—Perry's Gas Engine, 1

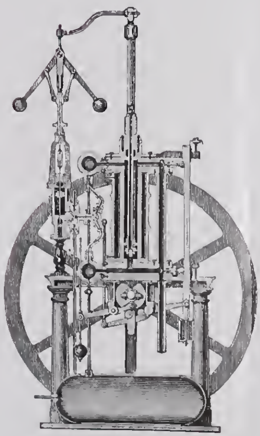


Fig. 3.—Wright's Gas-Exploding Engine, 1833.

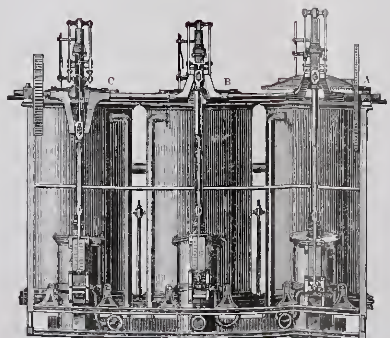


Fig. 2.—Brown's Vacuum Gas Engine, 1826.

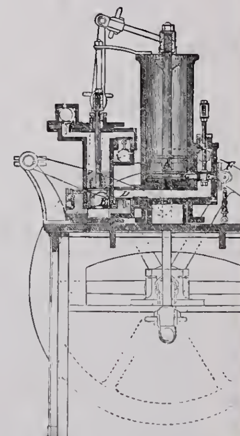


Fig. 4.—Barnett's Gas Engine,

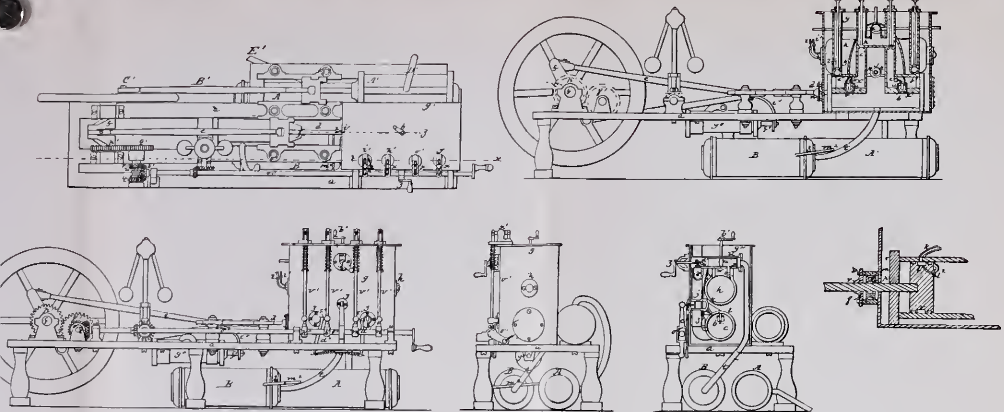


Fig. 7.—Perry's Gas Engine, 1846.

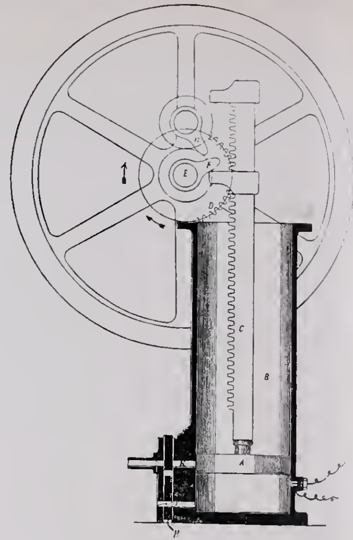
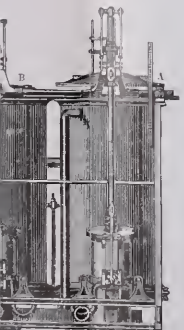


Fig. 9.—Barsanti & Matteucci, 1857.



m Gas Engine, 1826.

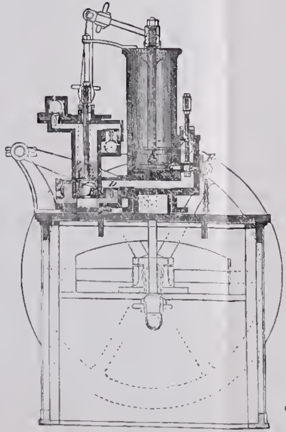


Fig. 4.—Barnett's Gas Engine, 1838.

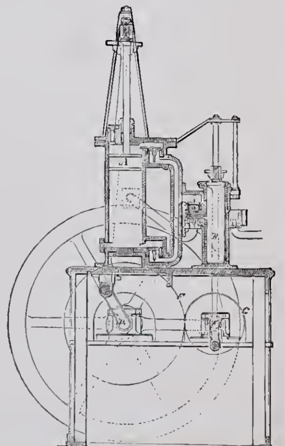


Fig. 5.—Barnett, 1838.

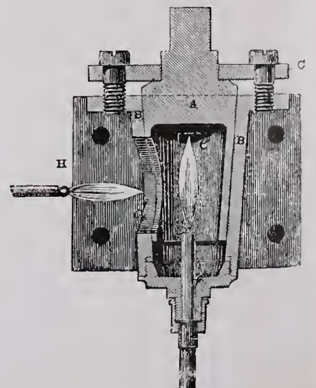


Fig. 6.—Barnett's Gas Igniter.

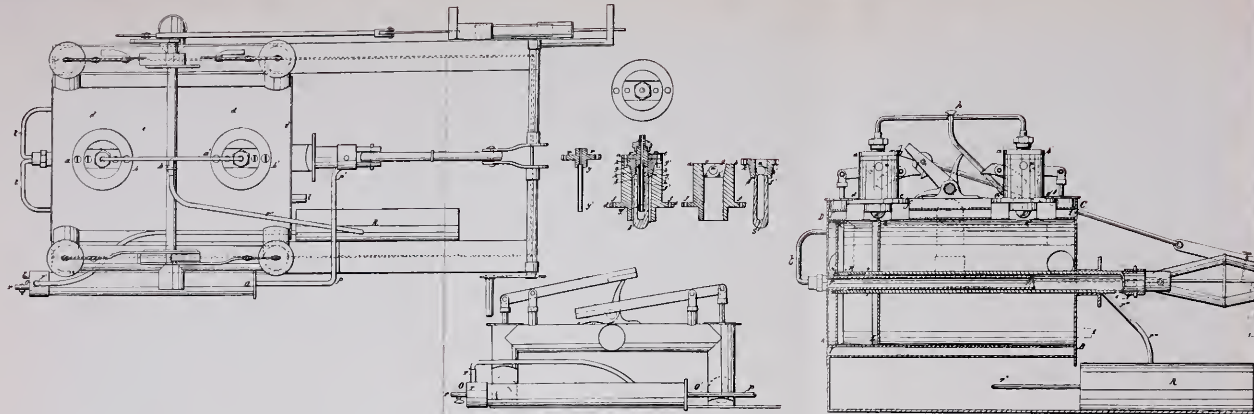


Fig. 8.—Drake's Gas Engine, 1855.

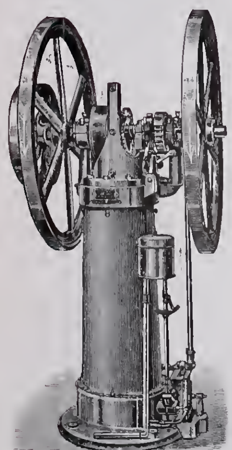
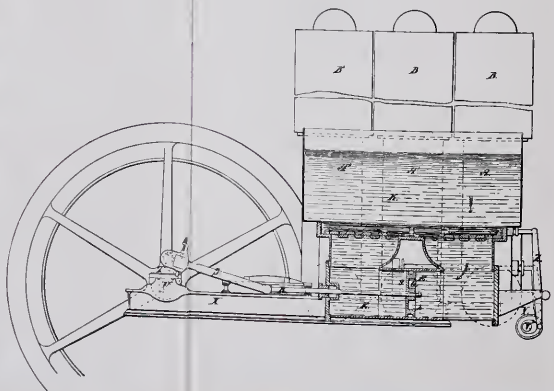


Fig. 10.—Otto & Langen Gas Engine, 185



F... Hugon Gas Engine, 1864.

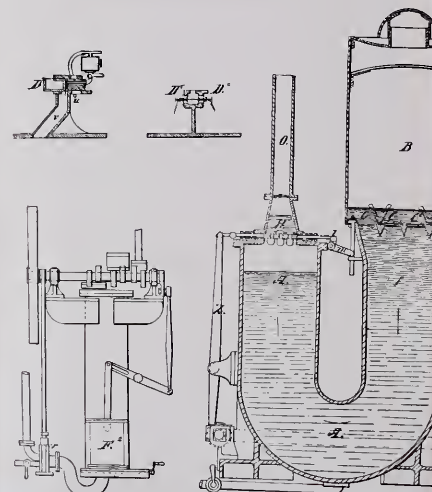


Fig. 13.—Hugon, 1864.

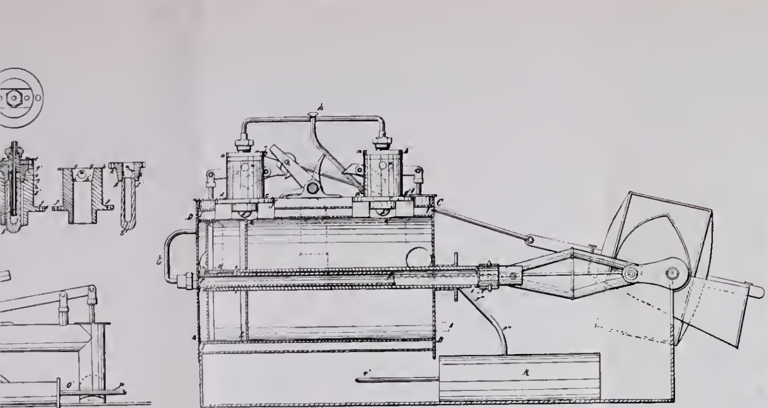


Fig. 8.—Drake's Gas Engine, 1855.

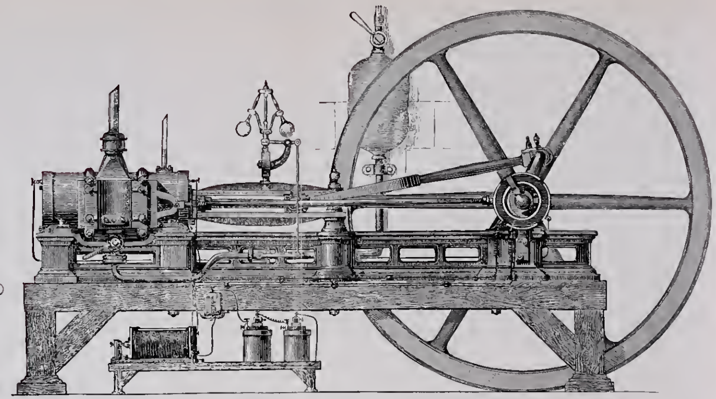
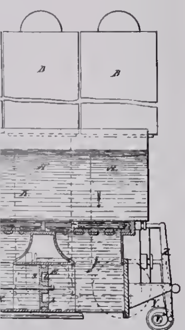


Fig. 11.—Lenoir's Gas Engine, 1860.



64.

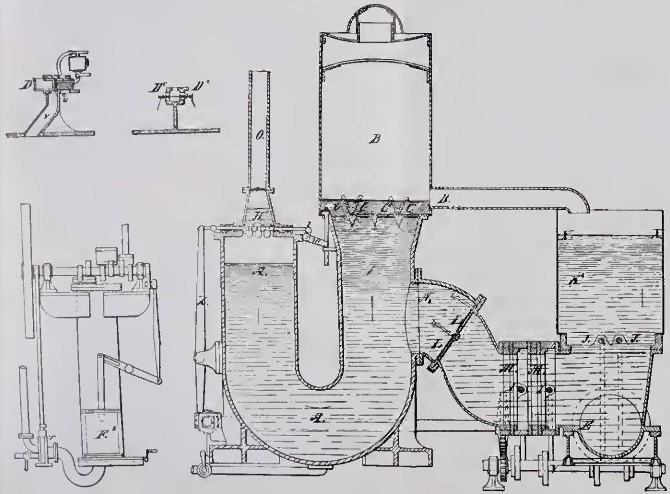


Fig. 13.—Hugon, 1864.

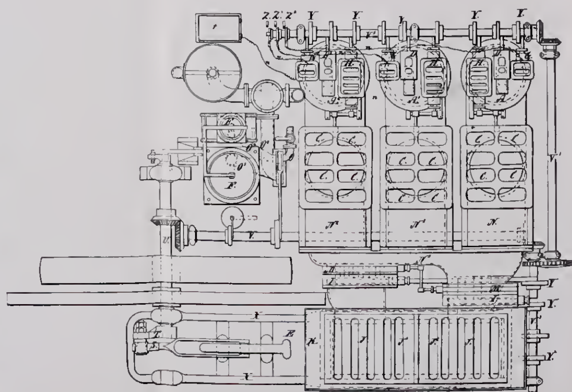


Fig. 14.—Hugon, 1864.

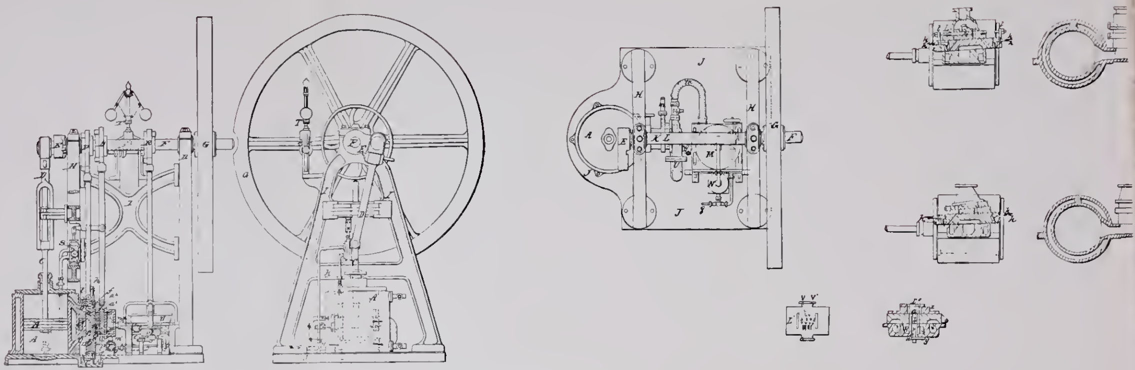


Fig. 15.—Hugon, 1865.

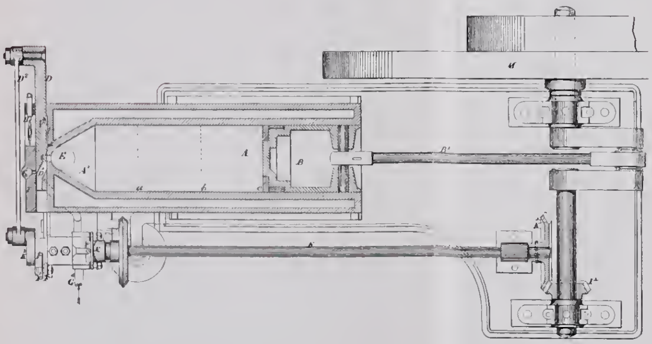


Fig. 16.—Otto Silent Gas Engine, 1[illegible]

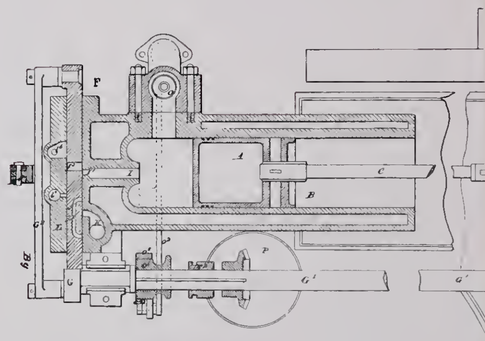
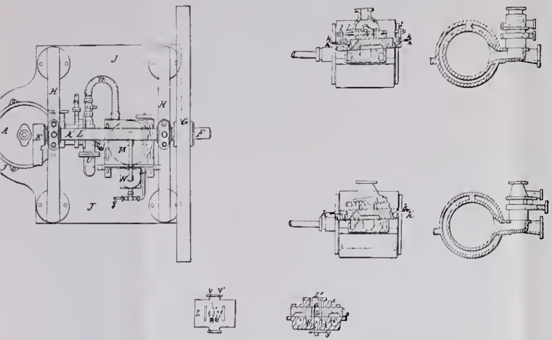


Fig. 17.—Otto-Crossley, 1877.



on, 1865.

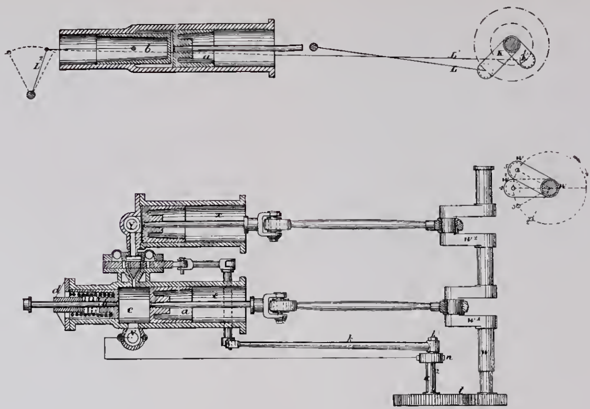


Fig. 19.—Otto Silent, 1881.

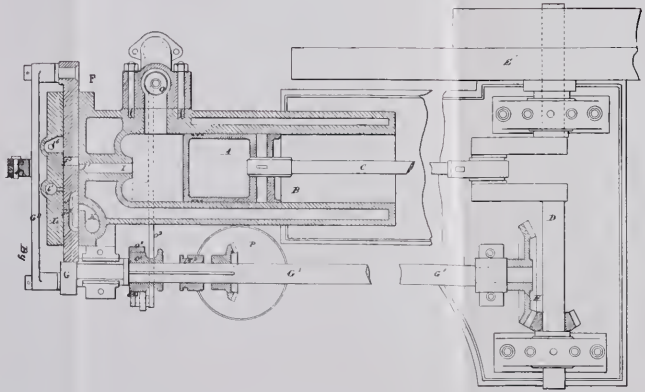


Fig. 17.—Otto-Crossley, 1877.

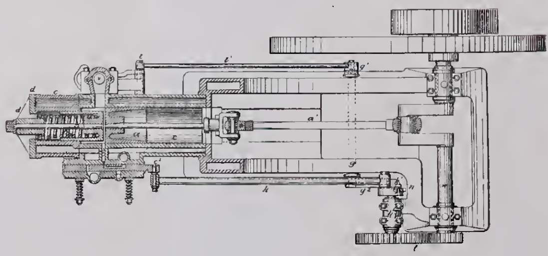


Fig. 18. Otto Silent, 1881.

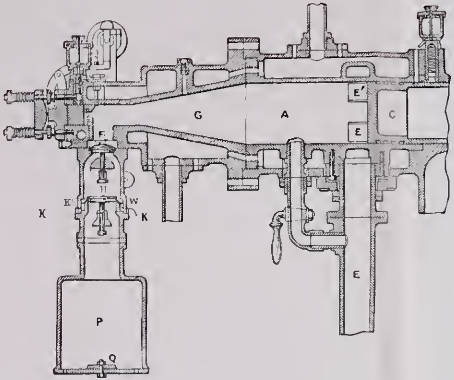


Fig. 22.—Vertical Section. Clerk, 1881.

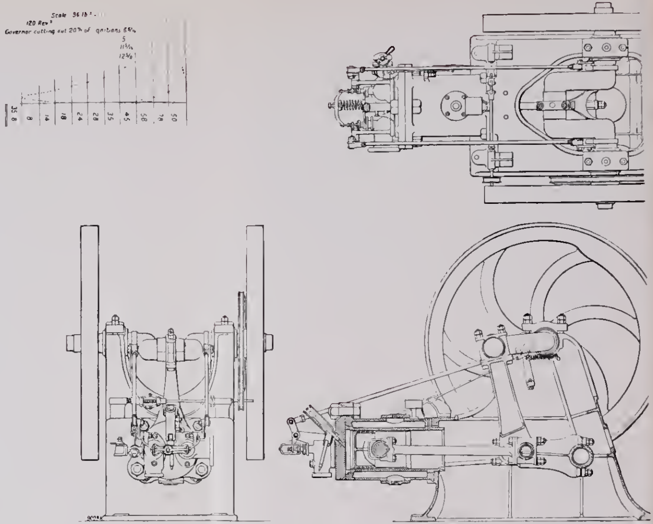


Fig. 23.—Atkinson, 1886. Section Plan, Rear Elevation and Indicator Diagram.

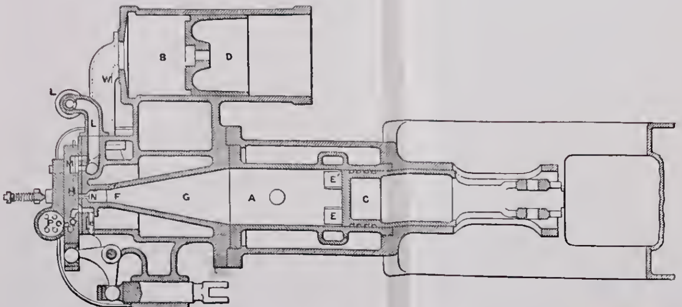


Fig. 21.—Sectional Plan. Clerk, 1881.

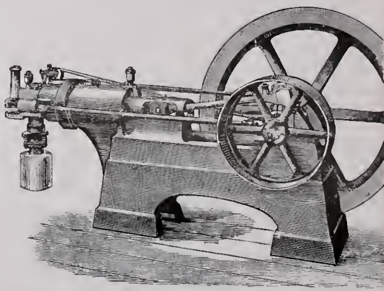


Fig. 20.—Clerk's Gas Engine 1881.

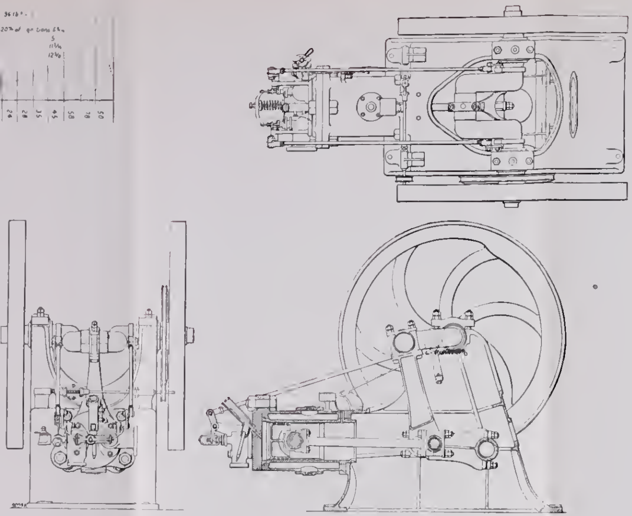


Fig. 23.—Atkinson, 1886. Section Plan, Rear Elevation and Indicator Diagram.

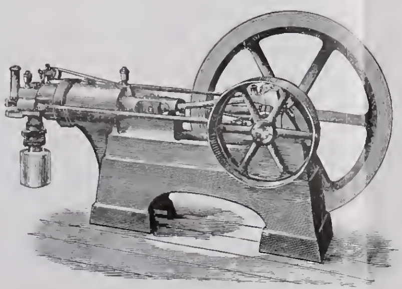


Fig. 20.—Clerk's Gas Engine, 1881.

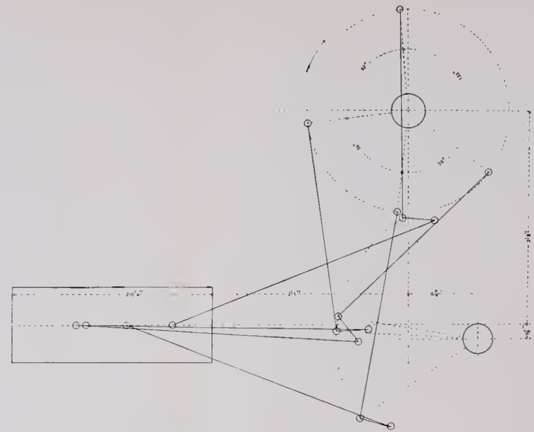


Fig. 24.—Skeleton Diagram of Atkinson's Gas Engine.

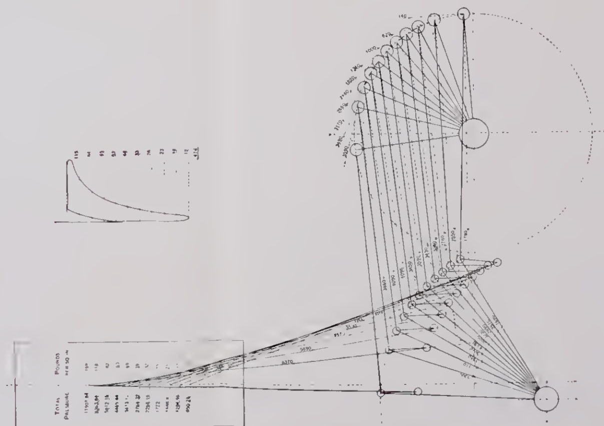


Fig. 25.—Force Distribution in Atkinson's Gas Engine.

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OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXVII. JUNE, 1889. NO. 6.

ON ATKINSON'S GAS ENGINE.

[*Report of the Committee on Science and the Arts.*]

[No. 1432.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 1, 1889.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

ATKINSON'S GAS ENGINE,

Report that: They have examined the said invention and the description and drawings thereof, as shown in letters-patent of Great Britain, No. 3,522, dated March 12, 1886 (*Fig. 1*), and find it to consist of a combination of crank, link and lever movements, with a single acting piston reciprocating in a cylinder, so that two strokes of the piston take place for each rotation of

the crank, one stroke making an entire displacement of the whole cylinder capacity, and the other stroke leaving a space between the piston and back-head of the cylinder. Into this space a mixture of air and gas is drawn and enclosed, next compressed, and then ignited or exploded, propelling the piston in the cylinder, and imparting motion by a link to a lever, connecting rod and crank. The piston then acquires from the crank, through the lever and link, a returning motion of the entire length of the cylinder, and expels the products of the combustion of the former charge; next the piston moves toward the front end of the cylinder, receiving a charge of air and gas equal to about half the capacity of the cylinder; and the piston then returning part way, compresses such charge of air and gas in the cylinder ready for ignition in the same manner as the former charge.

An engine, rated by the manufacturer at six horse-power, has been twice tested by your committee, and the results of these tests, which are tabulated and appended to this report, show such an economical performance as to impress them with the importance of the machine as a competitor with the steam engine as a generator of motive power, and to entitle it, upon its merits, to a full and careful examination.

In order that the operation and special features of construction of this engine may be readily understood, the committee deem it expedient to give a brief general account of the mode of operation of gas engines and of the preceding state of art in this field of invention.

The first attempt or suggestion of an engine operated by gas is the proposition of Huyghens, in 1680, to procure motive power from the gases generated by the ignition of gunpowder.

In 1690, Papin experimented in the same direction, but did not seem to achieve any useful permanent results. His mode of operation was to expel the air from a large vessel through check valves opening outwards, and upon cooling to make use of the force of the atmosphere flowing into the partial vacuum or rarefied gases in the cylinder. This force was made available by a piston working in the vessel, to

which piston was connected a weight to be lifted or other work.

This cannot strictly be called a gas engine as the explosion of gunpowder, containing within itself both elements, oxygen and the combustible so little resembles the explosion of gases made explosive with oxygen supplied from the atmosphere as to make the operation of such inventions entirely dissimilar.

The first appearance of record, among the patents for gas engines, properly so-called, is in Robert Street's British patent, No. 1,983, of 1794. In it is a cylinder provided with a piston connected by a lever to a pump. Heat is applied to the bottom of the cylinder, and a small quantity of spirits of turpentine was admitted to the cylinder and evaporated by the heat.

The piston moved upward and air entering mixed with the turpentine formed inflammable vapor; the flame applied at an aperture, ignited the mixture of air and inflammable vapor, and caused an explosion, driving the gas piston up and the pump piston down, thus working the pump to raise water.

A considerable interval of time elapsed before any other recorded gas engine appeared.

Samuel Brown, in his British patents respectively numbered and dated 4,874 of 1823 and 5,350 of 1826 (*Fig.2*), shows a gas engine, which, whilst possible to work, does not promise any economy, and is very cumbrous as compared with other devices, giving the same amount of power. It consisted of a series of vessels, in each of which in regular succession the air was excluded and expelled by flame produced therein. Each vessel was then closed and the rarefied air contracted by jets of water injected and cooling it.

The immediate motive force with this apparatus was the atmospheric pressure pressing into the partial vacuum.

In connection with this series of vessels, Brown employed several cylinders resembling the pistons and cylinders, and valvular constructions for admission and exhaust of direct acting steam engines, the pistons of which were attached by connecting rods to cranks placed equi-distant angularly in a

shaft so as to produce rotation of the shaft, the air flowing into the vacuum performing the same function that steam does in propelling the piston of an engine. The several chambers in which the vacuum was produced were operated successively, so that while one was being charged with gas and air, another was being cooled, and a third one was drawing in the air propelling the engine pistons.

Whilst this engine partakes very little of the character of the present modern gas engine, it bears about the same relation to the present gas engine as the early steam water-raising devices of Newcomen and Savery do to the present steam engine.

The next recorded invention is that of Wm. L. Wright's British patent, 6,525 of 1833 (*Fig. 3*). In this a double-acting cylinder and piston, like the piston and cylinder of the steam engine, was propelled directly by the explosion of a mixture of combustible gas and air acting directly upon a piston, and imparting motion through the usual devices of crank, connecting rod and a rotative shaft.

The air and gas were compressed by separate pumps under low pressure into reservoirs, and was thus forced into chambers at the end of the working cylinder, after ejecting or displacing the gaseous products, from the former stroke by the return stroke of the piston, the gas was ignited as the crank passed the centre; that is to say, when the piston was at rest, the explosion forcing the piston through its whole stroke. At the end of the stroke the exhaust valve opened, and the gases resulting from the. combustion were discharged by the returning motion of the piston up to a point where the charge was introduced, when the charge was compressed ready for the next stroke; the ignition was effected by a flame passing through an aperture into the cylinder.

No record appears of this engine ever having been made, although the drawing and specification illustrated and described its construction and operation very fully and clearly.

The cylinder and piston are cooled by a water-jacket, as in modern gas engines.

Next succeeding this is the engine shown in Wm. Barnett's British patent, No. 7,615 of 1838, and was a much more complete and better illustrated invention than any preceding one (*Figs. 4, 5* and *6*). The present system of igniting flame first appears in his invention.

Barnett's description in his patent embraces a single acting engine, and two forms of double-acting engines, all of which compress their charge of air and gas previous to igniting it.

This compression in the first two described forms of engines is effected by pumps, and receptacles distinct from the motor cylinder. The third form receives the charge of the explosive mixture from the pumps directly into the motor cylinder and the motor piston completes the compression of such charge.

The ignition takes place at the commencement of each stroke; that is to say, as the crank passes the centre.

The igniting apparatus consists of a hollow conical plug, which contains a gas jet tube, and has upon one side an aperture which on one position opens, so as to ignite the jet in the plug from an external gas jet. In another position, it closes the connection with the atmosphere and external gas jet, and opens communication with the motor cylinder. A portion of the compressed charge of air and gas entering the hollow plug causes ignition and explosion of the charge in the motor cylinder, and is substantially the present flame ignition system that is practised in modern gas engines.

On page 102, vol. xlv, JOURNAL OF THE FRANKLIN INSTITUTE, there is a brief description of the gas engine, patented October 7, 1846, in the United States, by Stuart Perry, of New York City. The drawing only has been published by the Patent Office, and is here reproduced (*Fig. 7*). In it the cylinder is surrounded with water, the gas is generated in the engine in a retort, the piston was to be lubricated with water, the gas ignited by platinum heated by gas jets in a chamber communicating at intervals through a valve with the explosive chamber.

Considerable attention appears to have been directed

towards the improving of gas engines by a number of applications for British patents, which took place between the date of Barnett's invention and 1855, most of which patents were not perfected, but were merely granted for provisional protection.

In the absence of any complete specifications of them, we, of course, are not informed as to their precise construction.

In 1855, Dr. Drake, of Philadelphia, made a gas engine, and patented it in the United States, on the 17th of April, 1855, in letters-patent No. 12,715, and communicated the invention to Alfred Vincent Newton, the invention is set forth in British patent 562 of 1855. The drawing of the United States patent is here shown (*Fig. 8*).

This engine has a double acting cylinder and piston, and receives a charge of mixed air and gas for part of the stroke, which becomes ignited by the piston uncovering an aperture about midway in length of the cylinder communicating with a cavity having in it a cup of metal or thimble heated to incandescence by an external blow-pipe flame.

This appears to be the first instance in which the gas was ignited by metal heated to incandescence by an external flame; the same device has since then frequently reappeared in other inventions.

Whilst Dr. Drake's engines were well known to numbers of persons in this city, and exhibited in operation to many who are still living, it does not appear that they were ever introduced commercially into use.

In the patent of Great Britain, granted to Barsanti and Matteucci, No. 1,655, of 1857, another type of engine appears (*Fig. 9*); in this a cylinder is provided with an air-tight piston free to rise and fall in it, with a rack attached to the upper side. The piston was elevated or projected upwards in the cylinder by an explosion of a mixture of gas and air beneath the piston and the rack engaged in, and turned a pinion upon a shaft bearing a fly-wheel. The gases cooling in the cylinder, the piston was forced downwardly by its own weight, and the pressure of the atmosphere into a partial vacuum in the cylinder, and turned the shaft by means of the pinion.

A valve at the base of the cylinder served to discharge the products of combustion, and a cam, on the shaft operating tappets upon the rack, served to again elevate the piston a little distance, so as to introduce a fresh charge of air and gas, which was ignited like the previous one and raised the piston again. A ratchet and pawl were provided, so that the shaft should move in one direction continuously, and offer no impediment to the turning of the pinion during the rise of the rack and piston.

These engines were afterwards, about 1867, improved and manufactured by Messrs. Otto & Langen, who added a centrifugal regulator controlling the igniting apparatus, and a cooling jacket to the cylinder (*Fig. 10*).

They were noisy, but were quite extensively introduced, and will be remembered by many as a feature of the Centennial Exposition, in this city, in the exhibit of Otto & Langen, and were commercially successful.

Lenoir's engine (*Fig. 11*) made its appearance about 1860.

In this machine the gas was admitted alternately on either side of the piston, working in the water-jacketed cylinder, and ignited by an electric spark from a Ruhmkorff coil and voltaic battery.

This engine found considerable sale, but was not economical and soon fell into disuse. The cylinders and pistons required frequent cleaning (with Philadelphia city gas daily, and even oftener), and the electric igniting device demanded almost constant attention to keep it in operative condition. Attempts to remedy their defects appear in the United States and British patent records, but seem to have been ineffectual.

In 1867, the Otto & Langen engine was introduced at the Paris Exposition. Its general construction we have already referred to in speaking of the Barsanti and Matteucci engine upon which it improved and showed some appearance of economy—forty-four cubic feet of illuminating gas producing an effective horse-power per hour, which was less than fifty per cent. of that required by the Lenoir or Hugon engine.

Pierre Hugon's first engine, patented to him in the

United States, January 19, 1864 (*Figs. 12, 13 and 14*), operated by displacing a water column by the explosion of air and gas, and moving the power piston in a cylinder by the reaction of the pressure of the water column, the purpose being to secure longer and more uniform action. This was speedily followed by his engine, patented August 8, 1865, in letters-patent of the United States No. 49,346 (*Fig. 15*); the latter being merely the Lenoir engine, with a flame ignition substituted for the electric spark. This ignition apparatus was in the form of a slide instead of the rotative device of Barnett. It is of the general character of the igniting slides now used in gas engines.

In 1876, the Otto "Silent" appeared, which embodied a scheme or method of working, described by Beau de Rochas, in a pamphlet published in Paris in 1862, which is here shown in the drawings from his United States patent 190,047, dated August 14, 1877 (*Fig. 16*). In this the piston derives its impulse from gas compressed in a chamber at one end of the cylinder, and having completed its outward stroke returns whilst the exhaust remains open, and the products of combustion resulting from the explosion and combustion in the outward stroke are expelled, as nearly as may be, by the next out-stroke which is made with the exhaust valve remaining open; the supply of fresh air and gas commingled with it, is received in the cylinder; the exhaust valve now closes, and the returning stroke of the piston, produced by the momentum of the fly-wheel and action of the crank and connecting rod compresses the charge of gas into the chamber at the end of the cylinder, and being ignited, another propulsion of the piston takes place, during one outward stroke only in every second revolution. In other words, three strokes of the piston without any development of power must occur to procure one stroke from which the fly-wheel and connecting parts receive any impetus.

This cycle of working is an essential characteristic of the modern gas engines of Otto, and the function effected by it of compression of the charge of gas and air are characteristic of all the present economical gas engines. The several inventions for improvements in gas engines are for the means and methods of effecting such functions.

The Otto gas engine has been improved in its details by Wm. J. Crossley, of Manchester, England, who has given the invention its present well-known form. There have been many improvements in details patented, which it is unnecessary to particularize in this report (*Figs. 17, 18 and 19*).

In the Clerk gas engine (*Figs. 20, 21 and 22*), the functions of purging, charging and compression are effected by means of pumps supplying air and gas. It will be seen upon inspection of any of these gas engines that the space occupied by the charge at the commencement of the power stroke, is beyond the displacement of the piston, and therefore may retain a portion of the products of combustion from the previous power stroke, which dilutes the next charge and impairs its effect.

The method of operation of all gas engines, as compared with other heat engines, as for instance steam, is essentially dissimilar. In the steam engine the heat is imparted to the fluid by conduction, a great deal of heat is required in converting water into the gaseous state or steam, and a great deal of heat is wasted, both in the combustion of the fuel and in its transmission through the material of the boiler, as well as by conduction and radiation from the pipes, valves, cylinders, etc. In the best steam engine this is diminished to the lowest point practicable by working rapidly, thus avoiding long contact of the steam with the working parts of the engine, and by protecting against radiation by slow conducting coverings. In the gas engine, the expansible fluid is atmospheric air, the fuel is the gas, which is commingled with the air, and contributes to its volume, and when ignited imparts its heat directly to the mixture instead of transmitting it through any intervening partition. The sources of loss of power in gas engines are the cooling of the gases and the air before imparting their force to the moving piston.

It is necessary in these constructions, from the high temperature resultant from the explosion or the combustion of the gas and air to maintain the cylinder at a much lower temperature than that of the gases, so that the correct fitting of the piston and cylinder may be preserved. This

is done by a circulation of water through a jacket surrounding the cylinder.

The best economy would indicate that the greatest capacity of the cylinder with the least surface would be the best proportions for such cylinders, and practice appears to verify this inference. To utilize the force with the least waste from conduction by the cylinder, and the quickest transmission of the force from the exploded gases through the moving piston to the fly-wheel (which is the reservoir of power in these engines), have proved to be the best practice.

The Atkinson gas engine (*Fig. 23*), which is the subject of examination and test by this committee, is an endeavor to combine these several indications of economical practice in a simple machine. Instead of making the two revolutions of the crank shaft to procure one impulse from the explosion of gas and air, the piston of this engine is connected indirectly by a peculiar system of lever and link or connecting rod to the crank, so that when the crank makes one-half revolution the piston passes out to the front or open end of the cylinder and returns close up to the back end thereof.

In the next half revolution, the piston passes out midway toward the front end of the cylinder, and makes only a partial return stroke, during which time it receives and compresses a charge of gas. This is ignited, and the piston is propelled outward a full stroke in less than a fourth revolution of the crank, and returns close to the back end of the cylinder, displacing all the products of combustion from the previous stroke, and leaving the cylinder free to receive an entire charge of air and gas.

The expansion of the charge after explosion is to about double its original volume and down to atmospheric pressure, thus utilizing all the force generated and not absorbed by the cylinder and piston as heat. The exhaust, as a consequence, is noiseless.

The arrangement of levers and links for effecting this are shown in the drawings marked *Fig. 1*, which show a lengthwise vertical section of the engine. The angular distances through which the lever, link and crank operate upon each other in performing their several functions, are shown in *Fig. 24*.

The distribution of force is shown in *Fig. 25*, as is also the pressure upon the piston by an indicator diagram on the same figure.

The resistance encountered during the short compression stroke is shown in the triangular shaded lower left portion of the diagram, whilst the large triangular part of the diagram represents the development and utilization of force. The relative areas of these figures indicate the extent of charge consumed and the economy derived from the expansion of the products of the explosion.

It will be seen that the absorption and transmission of power from heated gases through the piston, lever, link and crank to the fly-wheel is through a very short fraction of a revolution. The construction of the details of the engine is shown in the remaining figures. The admission of gas is made through an annular port surrounding the air-admission valve and ensures the mixing of the air and gas as they enter. The exhaust is discharged through a poppet valve controlled by a cam, and both valves are brought to their seats by a single spring operating a yoke to the ends of which these valves are connected. The regulation of velocity is by a centrifugal governor, which moving a block to one side or the other, as the speed may be accelerated or retarded, connects or disconnects the gas-admitting valve from its operating cam.

The ignition of the gaseous mixture is effected by a tube closed at the outer end, with one end open to the cylinder and the other closed and heated by an external flame from a Bunsen burner located inside of a non-conducting chamber or chimney.

It is found by observation that the six-horse engine under examination steadily maintained a remarkable uniformity of speed.

Two tests were made of the engine by your committee.

Records of these tests are here tabulated and shown. The engine was rated commercially as a six-horse-power engine. It developed a brake power in one experiment of 10·3 horse-power with an expenditure per brake-power of 22·25 cubic feet of gas hourly per brake.

Upon the second test it developed 8·6 per brake horse-power with the expenditure of 22·3 cubic feet of gas per hour per horse-power.

In making these tests the quantity and increase of temperature of cooling water were carefully noted.

For the purpose of ascertaining and apportioning the causes of loss or disappearance of the force due to the explosion of the gas consumed, the following data are submitted:

Assuming that the quality of gas supplied from the city works of Philadelphia to be equal to that of the London Gas Works, and containing 638·7 units of heat per cubic foot, then the absorption of the power appears in the work done on the brake, as 18·132 per cent. of the theoretic power of the gas. 26·87 appears in increased temperature of the cooling water, and the balance, about $\frac{35}{100}$, disappears as chargeable to losses by radiation, friction and imperfect combustion.

This while it looks very wasteful, when we consider how very little the best steam engines show of useful effect for the units of heat contained in the fuel, is not only remarkably good economy, but shows an inviting field open to further experiment, and promising remunerative economy.

The engine tested by your committee is of foreign manufacture. The manufacture of such engines embodying this invention is now being commenced in this city and promises to become an important industry.

In preparing the report your committee found it requisite to a clearer understanding of this subject to examine all of the specifications of the United States patents on this subject. In so doing they, of course, found much that was irrelevant to their present inquiry, but to discover what was requisite to guard against mistakes in finding the state of the art, no other course appeared safe.

The United States patent specifications and drawings inspected in this case number 188 patents, many of them containing several sheets of drawings. The foreign patents, some twenty-seven, are for the most part repetitions of the American patents.

The conclusions indicated by the test are that James

ATKINSON GAS ENGINE.—TEST I.

Time	Counter.	Revolutions as per Counter.	Gross Load.	Negative Pull.	Net Load.	Gross.	Remarks.
345 50	32 397	. . .	145¼	8	137 25	0	
48 45	·758	361	145¼	5¼	140 0	10	
51·32	33·111	353	145¾	1¼	14 40	20	
56 20	·455	344	145¼	½	144·75	30	
57 7	·799	344	145¼	¾	14·50	40	
59·50	34 139	340	145¼	¾	14·50	50	
2·35	·473	334	145¼	¾	14 30	60	
5·8	·805	332	145¼	¾	14 50	70	18, 1¾
7·55	35 138	333	145¼	¼	14·50	80	
10·35	4?4	326	145¼	0	145 25	90	Removed ; portion of load.
13·25	811	347	134¼	0	134·25	100	
·15	36·179	368	134¼	0	134 25	110	58. 4¼
18 5	36 525	356	134¼	0	134 25	120	59. 5¼
32·15	41·38	4.138			13)1,839·00 141 46		450

Time 32¼ minutes.
Total revolutions, 4,138; per minute, 128·3.
Net mean load, 141 46.
Gas in 32¼ minutes, 120 cubic feet.
Circumference, 18·24 feet.

$$\text{Brake horse-power, } \frac{18{\cdot}24 \times 128{\cdot}3 \times 141{\cdot}46}{33{\cdot}000} = 10{\cdot}03$$

Gas per hour, 22·32.
Gas per brake horse-power per hour = 22·25 cubic feet.

ATKINSON GAS ENGINE.—TEST II.

Time.	Difference.	Gas.	Counter	Difference.	Gross Load.	Net Pull.	Net Load.	Water. Gross.	Water. Net Pounds	Water. Temperature Inlet.	Water. Temperature Outlet	Remarks.
h. m. s.					pounds				pounds	deg. F.	deg. F.	
2 33 50	. . .	0	39,553	. . .	133	1·5	. . .	. . .	. . .		. . .	
37 10	3·20	10	935	382	. . .	1·5	. . .	. . .	. . .		. . .	
40 25	3·15	20	40,309	374	. . .	1·5	. . .	. . .	. . .		. . .	
43 33	3·8	30	683	374	. . .	1·5	. . .	. . .	. . .	43	111	
46 47	3·14	40	41,055	372	. . .	1·5	. . .	. . .	. . .	43	107	
49 57	3·10	50	424	369	. . .	1·5	. . .	. . .	. . .	43	110	
53 0	3·3	60	790	366	. . .	1·75	. . .	. . .	. . .	. . .	114	Missing about 10 per cent. of charges.
56 4	3·4	70	42,156	366	. . .	1·8	. . .	. . .	. . .		120	
59 7	3·3	80	520	364	. . .	1·8	. . .	. . .	. . .	. . .	1 6	Little more water.
3 2 10	3·3	90	885	365	. . .	2·	. . .	. . .	. . .	. . .	115	
5 15	3·5	100	43,250	365	. . .	2·	. . .	. . .	. . .	. . .	113	
8 22	3·7	110	618	368	. . .	2·	. . .	. . .	. . .	. . .	111	
11 25	3·3	120	982	364	. . .	2·	. . .	. . .	. . .	. . .	107	
14 34	3·9	130	350	368	. . .	2·	. . .	. . .	. . .	. . .	104	
17 39	3·5	140	719	369	. . .	2·	. . .	. . .	. . .	. . .	. . .	
20 43	3·4	150	45,088	369	. . .	2·	. . .	. . .	. . .	. . .	98	
23 47	3·4	160	459	371	. . .	2·25	. . .	. . .	. . .	. . .	97	
26 50	3·3	170	815	356	. . .	2·25	. . .	. . .	. . .	. . .	92	
30 0	3·10	180	46,183	368	. . .	2·25	. . .	. . .	. . .	. . .	92	
33 0	3·0	190	541	358	. . .	2·5	. . .	. . .	. . .	. . .	92	
36 5	3·5	200	46,913	372	. . .	2·5	. . .	. . .	. . .	. . .	93	
						21)40·10					17)1792	
1 2 15	1 2 15	200	7,360	7,360	133 —	1·91 =	131·09		546		105·4 — 43 = 62·4	

Duration of test, 62¼ minutes.

Net load on brake, 131·09 pounds.

Total revolutions, 7,360.

$$\text{Revolutions per minute, } \frac{7{,}360}{62\frac{1}{4}} = 118{\cdot}26.$$

Effective circumference of brake, 18·26 feet.

$$\frac{131{\cdot}09 \times 18{\cdot}26 \times 118{\cdot}26}{33{,}000} = 8{\cdot}6 \text{ BRAKE HORSE-POWER.}$$

$$\frac{200 \times 60}{62\frac{1}{4}} = 192{\cdot}8 \text{ cubic feet of gas per hour.}$$

$$\frac{192{\cdot}8}{8{\cdot}6} = 22{\cdot}3 \text{ cubic feet of gas per hour per brake horse-power.}$$

Committee on Science and the Arts, Franklin Institute.

Atkinson Gas Engine.—Test I.

Time.	Counter.	Revolutions as per Counter.	Gross Load.	Negative Pull.	Net Load.	Gross.	Remarks.
345·50	32·397	. . .	145¼	8	137·25	0	
48·45	·758	361	145¼	5¼	140 0	10	
51·32	33·111	353	145¼	1¼	14·40	20	
56·20	·455	344	145¼	½	144·75	30	
57 7	·799	344	145¼	¼	14·50	40	
59·50	34·139	340	145¼	¼	14·50	50	
2·35	·473	334	145¼	¼	14 50	60	
5·8	·805	332	145¼	¼	14·50	70	18, 1¾
7·55	35 138	333	145¼	¼	14·50	80	
10·35	464·	326	145¼	0	145·25	90	Removed 3·12 portion of load.
13·25	·811	347	134¼	0	134·25	100	
·15	36·179	368	134¼	0	134·25	110	58. 4¼
18·5	36 525	356	134¼	0	134·25	120	59, 5¼
32·15	41·38	4,138			13)1,839·00 141 46		450

Time 32¼ minutes.

Total revolutions, 4,138; per minute, 128·3.

Net mean load, 141·46.

Gas in 32¼ minutes, 120 cubic feet.

Circumference, 18·24 feet.

$$\text{Brake horse-power, } \frac{18{\cdot}24 \times 128{\cdot}3 \times 141{\cdot}46}{33{\cdot}000} = 10{\cdot}03$$

Gas per hour, 22·32.

Gas per brake horse-power per hour = 22·25 cubic feet.

Atkinson's gas engine surpasses all preceding gas engines in simplicity, economy, perfection of regulation, and uniform steadiness of power, and is deserving of recognition by an award of the John Scott Legacy Premium and Medal.

[Signed] S. LLOYD WIEGAND,
Chairman Sub-Committee.

WM. H. THORNE, LUTHER L. CHENEY,
COLEMAN SELLERS, E.D., SAMUEL R. MARSHALL,
MOSES G. WILDER, ARTHUR BEARDSLEY.

Adopted May 9, 1889.

[Signed] S. LLOYD WIEGAND.
Chairman Committee on Science and the Arts.

BLINDNESS AND THE BLIND.

By L. WEBSTER FOX, M.D.

[*A lecture delivered before the* FRANKLIN INSTITUTE, *February 25, 1889.*]

The Lecturer was introduced by Prof. EDWIN J. HOUSTON, of the INSTITUTE, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

"The character of a man may be read in his face." * I make an addendum and say, a man's character may be read in his eye. Physiognomy is understood by all to a greater or lesser degree. The physiognomy of the eye is the more subtle science, hence requiring a more extended study.

The eye is an index to the workings of the brain: "It participates in all its emotions, expresses the most lively sensations, passions the most tumultous, feelings the most delightful and sensations the most delicate." † One author calls it, "The tongue of the understanding."

We all feel that vision is the most valuable of the senses, for by it we enjoy the beauties of nature, it is also a source of our learning and a medium of communication. While

* Lord Kames. † Lavater.

modern methods have given the blind better advantages for knowledge, yet even the senses retained by the blind seem to be less acute to external impressions, than to those who have vision.

The most unfortunate affliction to any one, is to lose his sight. Goethe says: "To live and not see is unfortunate." Milton, the great poet, suffered with a disease of his eyes which eventually ended in blindness. At that time the nature of his malady was not understood. Science has advanced, and such cases are now successfully treated. Milton's blindness was to him a great grief. His mind was of the brightest, and most prolific in gems of noblest thoughts.

One could almost fancy that he would have lived within himself and been happy with his thoughts, but no, he says:

> "Thus with the year,
> Seasons return, but not to me returns
> Day, or the sweet approach of eve or morn,
> Or sight of vernal bloom, or summer's rose
> Or flocks or herds or human face divine:
> But clouds instead, and ever during dark
> Surround me, from the cheerful ways of men
> Cut off, and for the book of knowledge fair
> Presented with a universal blank
> Of nature's works, to me expunged
> And wisdom at one entrance quite shut out."

In strolling through an unfrequented street of London, several years ago, I found on the shelves of an old book stall, a book which attracted my attention, the title of which was, "Blindness and the Blind." It was of more than ordinary interest to me, and from time to time I have read it with renewed interest. From its title, I have taken the subject for my lecture this evening, and as I have gained much information of interest to me from this work, I have taken the liberty of making several extracts from the same.

Probably at no time in the history of the science of medicine has there been so much attention given to the effort to prevent blindness, correcting visual defects, or

operations devised for the restoration of vision, than at the present day.

In my rambles through the picture-galleries of Europe, I do not remember of ever seeing a single portrait where any defect of the eye had been noted. It would be difficult to portray a cataract, but one would expect to see an occasional crossed eye. Sometime ago I had the opportunity of becoming the owner of a few engravings of celebrated men of years ago. In this collection, I found two defects, one a crossed eye, the other, where the color of one was unlike its fellow, one being gray, the other being black or brown. I remember having once seen a negro child whose color indicated a pure African descent, yet this child had beautiful blue eyes.

Before entering into the subject germane of my lecture, I must speak of the very great importance which light plays in the development of vision and the assistance which the eye receives from it in the performance of its functions. The immediate instrument of visual perception, light, enables us to distinguish colors, to recognize form and to measure distance. Light may be too intense, too overstimulating, when this takes place we are as liable to have blindness as in its absence.

Any theory which supposes the properties of an external world to be only those which the mind can create for itself, mistakes the question. External properties may, and do, exist without our perception of them, and any failure to perceive is not proof against an external existence. Others may, and do, see that which we, for a time, fail to see, or have not the capacity for seeing.

The overstimulating effect of light on the human eye is to be noted by the effects produced. Since the introduction of the electric light into workshops, a new disease has developed. I may state that as soon as the attention of the medical profession was called to this fact, the light was rendered less intense, and the evils caused by it have disappeared. Occasionally we still find workmen who are subjected to this torture. It is a well-known fact that men who work in furnaces or puddling mills are subject to premature cataracts.

The enthusiast, who watches a solar eclipse without protecting his vision, pays for his rashness by developing a central blind spot which may not disappear for years, or may leave him permanently blind. Dr. Whitney reported seven cases of premature injury to the vision in Japanese students from exposure to sunlight during the last eclipse. On another occasion, an engineer was rendered blind by exposure to the light of a powerful electric arc. The intense glare of the snow is also productive of blindness. It is not unusual for woodsmen or hunters to become so affected. The intense glare of the tropical seas also produces blindness, known as "moon-blindness," erroneously attributed to the effect of the rays of the moon, but in reality caused by the sun's rays.

Light is essential for the development of vision, as the retina must have a certain amount of stimulus to develop its action. In illustration of this fact we may simply refer to the blind fish of the Mammoth Cave.

Disease, in various forms, plays a part in causing blindness. At one time small-pox was a most prolific cause of loss of sight. Measles and other eruptive fevers still cause much blindness. In thickly populated countries, where about one-third of the population become affected, visual defects, in consequence, are enormously great. In hot and dry countries ophthalmia is exceedingly prevalent. Napoleon, when in Egypt, had at one time about one-fourth of his army affected. This form of disease is exceedingly contagious, and a similar form of disease finds its origin in schools and institutions where cleanliness is overlooked.

Epidemics of pink-eye still live within the recollection of many present this evening. While these diseases do not, as a rule, lead to blindness directly, yet the secondary results are baneful.

In looking over the statistics, I find that the social life of a country has much to do with the development of vision. The Germans are proverbially near-sighted. In walking through the street of any garrisoned city of the German Empire, one is struck by the number of officers wearing glasses. The English, as a nation, are far-sighted. In our

own country we find the same law holding good. The community, descendants of English, retain this primal defect of their ancestors. The German community the same. Where there has been a commingling, the prepotency of the stronger is shown, and the "American eye" is the result. By this I mean the astigmatic eye. Astigmatism may be either of that kind known as far-sighted or near-sighted, or a mixture of both.

A very interesting examination of Indian school children was made by myself some years ago. Those just from their Western homes or those who had been in school but a very short time I found had exceedingly good vision, above the average of the American boy or girl. When I came to examine the boys and girls of the Creek tribe, here I found that civilization had placed her hand upon them. Near-sighted ones were common. This tribe, let it be remembered, have been more or less civilized for fifty years.

To prove still farther that class application, and especially the amount of study now required by teachers and possibly by directors of our public schools, is making the younger generation a generation of myopes or near-sighted individuals, let me quote from Dr. Cohn, who examined 10,000 school children, 17·1 per cent. or more than one-sixth of whom were near-sighted. No village children were found to be short-sighted until they had been at least half a year at school. Dr. Derby, of Boston, found the same defect co-existing to a greater or less degree with the time students had spent at Yale. My friend, Dr. Risley, of this city, some years ago, made a careful examination of the eyes of children attending the public schools. He found many defects. Beer, the famous ophthalmic surgeon, seventy years ago wrote against forcing school children. He said: "I have done much to impress upon parents and friends, in the most friendly manner and upon the most convincing grounds, the mischievous effects upon the eyes of growing children of the forcing system of the present day in schools." Note the result. Anyone who has travelled through Germany or Austria is struck by the number of

individuals wearing glasses. Three generations have passed away since Beer wrote the above sentences, but his prophecy has born its fruit. The Germans are to-day a near-sighted race.

Workmen on fine work always complain of defective vision. So common are these troubles that physicians have long ago ceased to give such diseases technical names, but such names as illustrate the occupation of the individual.

The ancients knew that the glare from white hot metals would cause blindness in a very few moments, and was a frequent means of punishment for their criminals or prisoners of war. It was supposed that Samson was in this way blinded by the Philistines. Nebuchadnezzar blinded Zedekiah by this means. Levy tells us that Pope Paschal, in 824, put out the eyes of every monk who preached fidelity to the Emperor of Germany. In 873, Charles the Bald, King of France, put out the eyes of one of his sons, who, having been made a monk against his will, had escaped and set his father at defiance. In 1004, the King of Poland conquered Bohemia and destoyed the vision of its duke. These horrors are surpassed by the fiendish conduct of the Emperor of Basilus, who, having in 1013 defeated the Bulgarians, put out the eyes of his prisoners, 15,000 in number, leaving only one person in a hundred with one eye to guide the sightless beings to their homes. Even in England, blinding prisoners of war or state was a common mode of punishment. It is said that Ivan the Terrible, Czar of Muscovy, after the completion of the cathedral in Moscow, had the eyes of the architect put out, lest he should ever construct another building equal to it in beauty.

As I stated previously, ophthalmia was a prolific source of blindness. It is said that in the twelfth century the streets of English towns were beset by Crusaders who had returned from the Holy Land, where they had lost their vision from this disease. In France, the attention of good King Louis IX was called to the large number of these blind individuals wandering about the streets of Paris, and, in 1260, founded an institution for their reception, where, to this day, the good work then done is shown in the magnificent

institution, where the blind from all parts of France are admitted. I visited this institution recently, which is now the oldest institution for the blind in Europe. At this time I take the opportunity of mentioning, and with just pride, that among the many charitable institutions of Philadelphia, none rank higher in their record of good work than the Institution for the Blind, at Twentieth and Race Streets.

There is one kind of blindness, I am sorry to say, for which the American Continent may be held responsible. While many cases do not exist, yet they are to be found. I believe, however, that it is a more frequent source of injury to vision than we like to admit. I refer to the abuse of tobacco. Tobacco abuse, while it may lead to absolute blindness, first may weaken the muscles of accommodation, thereby causing no end of visual difficulties, but also producing loss of power in recognizing colors or color-blindness, a defect, which, when existing among engine drivers, may peril the lives of many people entrusted to their care. At the last meeting of the British Medical Association, held in Glasgow, Dr. Bickerton, of Liverpool, read a paper on "Sailors and their Eyesight," including color-blindness. He is persuaded that many accidents at sea, both collisions and strandings, are caused by defective eyesight. To begin with color-blindness, Dr. Bickerton gives two cases in which accidents have been proved to have been directly due to this cause. Both accidents happened in our own country. The first is a collision which took place, in 1875, near Norfolk, Va., between the steam tug *Lumberman* and the steamer *Isaac Bell*. The master of the former vessel asserted that before the collision he saw the latter's red or port light, and manœuvred his own ship accordingly. All the other evidence proved beyond a doubt, that only the green or starboard light of the *Isaac Bell* could have been visible to the *Lumberman*. The master's mistake, through which ten lives were lost, remained inexplicable until a surgical examination, four years later, proved him to be color-blind. These facts are attested by the Annual Report for 1880 of the United States Inspector General of Steam Vessels. The second case is given on the authority of the

Shipping and Mercantile Gazette and Lloyd's List. It is there stated that the steamer *City of Austria* was lost in the harbor of Fernandina, Florida, in April, 1881, owing to the defective eyesight of the pilot, who was unable to distinguish the colors of the buoys. Dr. Bickerton, in addition, mentions the collision which took place last January between the *Toronto* and the *Freidis*, in St. George's Channel. In that case, according to the evidence given at the Board of Trade inquiry, the lookout man saw, before the collision, only a green light; while the captain, mate and quartermaster saw first a red and then a green one. The man denied that he was color-blind, but, as Dr. Bickerton stated, it was in the last degree unlikely that he would admit such a defect. The last instance given is the too notorious collision between the *Vanguard* and the *Iron Duke*, in 1875. That collision was due to the fact, that the *Iron Duke* steered out of line just when the *Vanguard* was slackening her speed, and this reduction of speed, without which the collision would not have taken place, was due to the report of the lookout man that a ship was crossing the bows of the iron-clad. Nobody else saw this ship, though four other men were on the lookout, and the man who reported her admitted afterwards that his eyesight was defective and that he had been twice treated for blindness of the right eye. The facts of this case are given on the authority of the official reports of the court martial; and here, at any rate, it seems clearly established that defective eyesight was a contributing cause of a most disastrous collision. On board the ships of our Trans-Atlantic lines, we believe, the utmost care is taken in the selection of men for the responsible post of lookout. As Lord Brassey, speaking of the *Vanguard* case, said in the House of Commons: "The entire management and manœuvring of a ship by the officers in command may depend on the experience and judgment of the men on the lookout aloft, and if they are not efficient, the gravest consequences may ensue." It therefore becomes evident that as long as signals at sea are given by colored lights, color-blindness is a fatal defect in a lookout man, and as the side lights, which every vessel carries to indicate her position

and course, are red and green—the two colors most commonly confused—the defect, when it exists, is particularly apt to lead to disastrous results. In fact, the authorities have recognized the force of these *a priori* considerations by making it compulsory upon all persons presenting themselves for officers' certificates to submit to a color examination. In our country, the subject of color-blindness has received much attention, and we may all feel sure that our engine drivers are men who can distinguish the difference in shade between a bright scarlet or a green light. When we know that forty men out of every thousand have this defect to a greater or less degree, we see the importance of having such men undergo an examination. It would be to the advantage of all boys to undergo such an examination once in their school life. Where the defect exists, let them know it, and their life work be so arranged for them that at some epoch in their lives they may not find themselves disqualified for following an occupation selected for them. A color-blind would be useless where the selection of color entered into his life work. Color-blinds make the best etchers, steel engravers, or wood engravers, for they possess what is known to their profession as the "recognition of tone." The man having normal color-sense depends on shade. But two women in one thousand are color-blind. The savage races possess the perception of color to a greater degree than the civilized races. In an experience of ten years I have found only one individual who was totally color-blind. Those blind to red and green, as I stated previously, are common. The usual tests for color-blindness are the matching of wools. Not the naming of colors, as names vary, and what might be called light green, might in some other language be called a light blue, and the individual who makes the assertion be perfectly correct. A person might in this way be put down as a color-blind, when it was simply a case of mistaken nomenclature.

A color-blind engineer on a clear night could not very easily make a mistake in recognizing his danger signal, for he will long before have learned that the light from the red light is not as clear as that from a white or even so much as

from a green. This is the reason why it is found that color-blind engineers have escaped accidents. I can recall an incident of this kind. A number of color-blinds were tested in the ordinary way, by red and green lights. It was soon found that two out of three men recognized the colors correctly. Our tests were carried on in the open air on a dark, but clear night, with the stars shining bright. It puzzled us very much. Suspecting that the men had certain information which they were using, they were taken into a building and submitted to the same tests, with a result which proved them to be color-blind. They then confessed that they had used a bright shining star as their guide. The light from the green light approached the light emitted from the star, yet when the red light was turned on, the light was not nearly so bright as the white or green light. One of the simpler ways of testing for this defect, is by placing before the candidate a large collection of wools, including all the chief colors, and several shades of each. Prof. Holmgrens test is to choose a rose color. The candidate will then be asked to match it. If his perception is good he will promptly select the rose wools, if he is red blind he will select the light blue, or violets, if green blind, the light grays or drabs. Rose being compounded of two parts red and one of blue, he would therefore select a blue, to match, as he would think, a blue. The second test would be a more pronounced one. We would then give him a scarlet. To this a red blind would match a dark brown, or a dark green. A green blind, would match a light brown and a light green. Dr. B. Joy Jeffries, of Boston, was a pioneer investigator in this country. It has been suggested that this sense should be developed by training or practice. This is simply impossible. Color-blindness may be the result of disease, brain disturbance, or congenital. One of the most brilliant teachers of Moorsfield Eye Hospital, London, recently went blind from an affection of the optic nerve. The first symptom of failing vision was his loss of color perception.

It is not infrequent to find individuals who work on colored goods, to find certain colors more fatiguing to their

eyes than others. Physicians now recognize a disease known as "weavers' disease." The red colors, which have the longest wave length, exhaust the eye first, the green follows second in order, while the blue is soothing. All are familiar with the phenomena produced by gazing steadily at a red disk or red letters, under bright illumination. Suddenly turning our eyes against a white background, we will soon recognize the same spot or the letters in the same color, which will, in a very short time, be replaced by the complementary color, green. This is due to retinal exhaustion, which for the time is unable to perceive the red element, but sees only the bluish-green produced by the admixture of the still visible green and violet.

Color in medicine may some day play a *rôle*. Psychophysics is a subject which the Germans are now discussing. Dr. Brodham, who has recently been making experiments for the purpose of testing the fundamental law of psychophysics in connection with the sense of sight, says: "If it can become known certainly, that the perception of color has a distinct and important influence upon the arrangement and interaction of the brain cells upon each other, we shall be able to drop the use of drugs to a great extent, and get our curing as we get our ailments, largely through the eye." This quotation has more pith in it than we should at first surmise. Recently I had an individual tell me that the color yellow would produce a nausea, and even an exceedingly bright day would bring about the same affection. A pair of Arundel-tinted glasses gave relief.

Do the blind enjoy the sense of sight in their dreams? This subject has lately been under discussion, and Professor Jastrow, who has personally examined 200 cases, has gathered some very interesting data. Of fifty-eight cases, which he quotes specially, thirty-two became blind before completing their fifth year, and not one of these thirty-two see in their dreams. Six became blind between their fifth and seventh years. Of these four have dreams of seeing, but two of them seldom, and with some vagueness, while two never dream of seeing at all. Of twenty persons who became blind after their seventh year, all have dream vision. Dr.

Jastrow remarks that, "the period of dream vision is from the fifth to the seventh year. If blindness occurs between the fifth and seventh years the preservation of the visualizing power depends on the degree of development of the individual. If the faculty is retained, it is neither stable nor pronounced. If sight is lost after the seventh year, the sight centre can, in spite of the loss, maintain its functions, and the dreams of such individuals are hardly distinguishable from those of a seeing person." Dr. Jastrow brings out the very interesting fact that the chief sense with the totally blind is hearing, and not the sense of touch. Dr. Hermann, in 1858, wrote a very interesting article on this subject. I quote from Dr. Jastrow's paper: "Dr. Hermann records the answers of fourteen totally blind persons who lost their sight previous to their fifth year, and none of them had dream vision. Of four who lost their sight between the fifth and seventh year, one had dream vision, one has it dim and rare, and two do not definitely know. Of thirty-five, who became blind after their seventh year, all have dream vision. Dr. Hermann includes in his list many aged persons, and from their answers is able to conclude that, generally speaking, those who become blind in mature life retain the power of vision longer than those who become blind nearer the critical age of five to seven years. He records twelve cases whose dream vision continues after a blindness of fifteen years, four of from fifteen to twenty years, four from twenty to twenty-five, and one of thirty-five years. In one case dream vision was maintained for fifty-two years, and in another fifty-four years, but these faded out."

I have for more than a year past given much attention to this subject. Those who have been blind from birth, or early childhood, do not enjoy sight in their dreams. For two reasons, first, they, like the rest of humanity, picture in dreams what they are accustomed to do in their day life, and as they do not depend upon sight in the performance of their daily duties, it does not form any part of their dreams. Second, it is impossible for the blind to get a correct definition of sight, how then can the imagination form a picture when the

material with which it is to work does not come under its sway? The pictures formed by the blind in their dreams are as the arch without the keystone; the mass is confused, and the absence of sight, which is the keystone to the mental arch, prevents the dream from being complete. I have talked with those who have lost their sight in later life, and their dreams are similar to those of persons who see. That is to say, if an individual lost his sight to-day he would continue to see forms, but as time rolled on the mental picture would gradually grow fainter and fainter, so that one who had been blind for a certain number of years would never again see form. Those blind from infancy would in their dreams depend upon the sense of touch and hearing, as these are the means by which those who have been deprived of sight are made acquainted with what goes on about them. When such individuals dream, they seem to talk with those who have a part in their dream, and can distinguish their voices as they reply to questions. They may fancy that they see daylight, but such persons always experience a greater sense of loneliness than is actually felt by the blind, when compelled to rely on their own responsibility at such times. A blind person once told me that she dreamed of a human face. It seemed as if she wanted to become acquainted with its shape. She placed her hand over it, and found its shape to be what is termed oval. The expression was absent, but to this blind person the face seemed to lack nothing, for how would it be possible to miss that which she had never seen? One cannot picture the beautiful city of Paris as it really is without visiting it, and can the blind picture that which description fails to make clear?

In some instances, color may be distinguished by persons who have but slight perception of light. In one individual who was thus affected, the two most prominent colors were red and blue; pink and yellow were seen but very indistinctly, the reason being that she had difficulty in distinguishing them at all times, while, on the contrary, red and blue are more readily distinguished. Colors seldom appeared in her dreams, and, when they did, had a faded look. Light

is invariably seen in this patient's dreams. It is clear and silvery. Prof. Helmholtz recently called attention to the sensation of light which we have all noticed in the dark, and when the retina is at rest. This sensation he calls "Eigenlicht," a name which brings us back to the curious belief of the Greeks, and which is said to have been shared in by Descartes, that the eye has a light of its own which it sheds on the outer world.

Another person writes me: "Ocular vision, to a person blind from the time his memory begins, is a far greater stranger than is a view of heaven to the sighted person. The sighted person is able to form some idea of heaven by seeing some beautiful garden and letting his heated imagination play among the beauties and charms there. What has the person always blind to build upon in order to form an idea bearing even the slightest resemblance to ocular vision? When we take sufficient pains, we are able to trace in our dreams the cause to which each particular feature owes its origin. The causes are clear or dim, or almost unrecognizable, just according to the force of the impression upon the mind during wakefulness. Hence, a dream is an after-view of what we experience. How, then, is it possible for a person always blind to dream of seeing?" Several such persons, in answer to my questions, have declared that they have seen in their dreams. However, they failed to draw distinct features of it. Their picture was no picture —a mass void of shape and color. They threw the marble, stone and other materials in a heap, and said: "There's the mansion." I am led to believe that their answer was prompted by a certain unaccountable false shame of theirs in confessing their inability to see in their dreams. Several persons blind from birth, not merely intelligent, but intellectual ones, have told me that they could see in their dreams.

In reference to those who have seen, a young man writes me, "I lost my sight at the age of fifteen. In some of my dreams I see just as I had seen in my former life, partake of the same pleasures, such as reading, skating, base ball, swimming, etc.; and in other dreams I see everything, but

am almost helpless. In travelling the streets for instance, I use my cane instead of my eyes, and on reading I must hold my book close to my eyes, and, as it were, strain my sight, and often the print seems blurred. I often remember what I have read. (I have also composed a stanza of poetry in my dreams, and recited it after waking.)"

Another, who has been totally blind, not even having light perception, writes as follows: "Many persons are of the opinion that the blind can, and do see in their dreams. That during slumber, their eyes as it were are opened and they perceive the rays of light and objects at a distance, which are veiled from them during their waking hours. This erroneous idea is due partly to a want of proper consideration of the subject, and partly, perhaps, to the fact that there are some blind persons who say that they dream of seeing. It is strange how many fallacious ideas there are regarding the blind." There are some blind persons, who, in order to make themselves appear wonderful, often go beyond the bounds of truth, and their statements are too apt to be accepted as facts by the sighted, without considering whether they are true or false. As, for instance, the false notion that the blind can tell color by the sense of smell, or a dollar bill by the sense of touch. "The phenomenon of dreaming is the same with the blind as with the seeing. It is now generally believed that our dreams are the result of some past association. I believe that all of our dreams may be accounted for in this manner. Some of them appear strange and curious, but it is because we can no longer recall the association or impression, but that impression was once made upon the mind. If this is so, how can the person who has never enjoyed the sense of sight dream of seeing? What conception can a man blind from birth have of a ray of light, of color, or of objects seen at a distance? He might study the subject of the eye for a lifetime but his conception of it would be very obscure. He might learn from physics how images of objects are formed upon the retina, but no amount of study can tell him how an image looked to the eye. How is it possible for him to dream of seeing if he had no concep-

tion whatever of sight? It is the same as if you were to expect a person deaf from infancy to dream of music."

Farsightedness, or hypermetropia. The length of the eyeball plays an important factor in seeing at a distance. When the eyeball is too short to allow the rays of light to fall upon the retina, we have indistinct objects formed on the back of the eye. In hypermetropia the muscle known as the ciliary muscle, compensates in a measure, by allowing the lens to become more convex, which renders the distant object more clear. In youth this function is very pronounced. It recedes as age advances. As we approach middle life it is lost. For this reason one is obliged to use glasses when the forty-fifth milestone is passed. Frequently individuals with very good vision are obliged to wear glasses at forty. When such is the case that man or woman is far-sighted. Race peculiarities, shape of the head has much to do with this form of vision. The Anglo-Saxon races and savage races are far-sighted. Helmbold speaks of the exceedingly acute vision of the Indians of South America. My own examinations among Indians of our own country confirm this. As long as an individual has an out-door occupation, this form of vision plays very little importance in the life work of the person. But when such a person has an in-door occupation, then do a multitude of troubles arise. Among the first to show themselves, is headache. This trouble may take on the most aggravated form, as nausea, pain in and about the eyes, a tired and languid feeling. So well known are these symptoms that an ophthalmic surgeon at once recognizes the trouble, even the family physician, whose advice is frequently sought, at once advises the wearing of glasses properly adjusted. Many individuals after a visit to the opera or an art gallery will return home with a severe headache, and to this form has been affixed the name of "sight-seers" headache. The American who goes "globe-trotting" flies to Paris, visits the numerous picture-galleries, exhibitions, etc., or, as one tourist told me, visits forty-two cities in thirty-two days, and doing all the things set down in the guide book. Let that man be possessed of the least

degree of hyperopia, and he pays for his enterprise by having headache after headache. A pair of glasses would have saved him much misery. Fatigue is also responsible for an important share in its production. The ever changing of the eye whose focus of vision shifts at every turn requires a double effort to give clear vision.

(*To be continued.*)

A CONTRIBUTION TO METEOROLOGY.

MR. ESPY; DR. HARE; TORNADOES; HAILSTORMS.

By W. P. TATHAM.

In the lecture delivered before the FRANKLIN INSTITUTE, Nov. 19, 1888, and published in the JOURNAL for February and March, 1889, Vol. CXXVII, under the title "Some American Contributions to Meteorology," the author characterizes Mr. Espy thus: "Espy was a theorizer."

This is very unfair to Mr. Espy, who, though he had his theories (as every thinking man must have), was eminently an observer rather than a theorizer. Whatever was sound in his theories was based upon observations.

I venture to think that the system of observations, suggested, organized and conducted chiefly by Mr. Espy, while meteorologist of the joint committee of the American Philosophical Society and the FRANKLIN INSTITUTE, was more extensive, both as respects the time devoted to the observations and the area covered by them, than any other which has been recorded, conducted by private effort.

It is not desired to underrate the value of the influence of the two learned societies named, nor, of the services of the members of their joint committee. All of these contributed to the very important published results which led to Espy's appointment as head of the meteorological bureau of the War Department, and afterwards to the organization of the weather service of the United States, upon the introduction of the magnetic telegraph.

It appears, moreover, unfortunate for the learned professor of Harvard to come to the FRANKLIN INSTITUTE and praise Mr. Espy for his theories, wherein he was not always happy, and to dismiss, with a passing allusion, his pre-eminent merits in observation. Here the memory of his enthusiasm and his activity is still preserved, and here we have the original records of his work.

Avoiding the stormy discussions of fifty years ago upon the nature and causes of storms and tornadoes, it will be worth while to consider the phenomena upon which the controversialists agreed, to wit:

(1) A low barometer at the middle of the storm, indicating a low atmospheric pressure.

(2) A general inblowing of the wind towards the middle of the storm, often combined with rotary movement.

(3) An ascending current of air at the middle of the storm, often excessively violent.

Which of these three is first in the chain of causation? and then, what is the cause of this one?

The low atmospheric pressure at the middle of the storm cannot be the first, because it represents a partial vacuum, which would draw the air to it from every direction, vertically as well as horizontally. It cannot cause an ascending current.

A general inblowing of the wind cannot be first, because centripetal winds would cause a *plenum* at the centre and not a *low barometer*.

There remains then, as the first cause among the three, the ascending current of air, occasioned by some influence besides either of the other two phenomena.

An ascending current of air would naturally cause a low barometer beneath it and an inblowing of wind from every lateral direction to re-establish the equilibrium. This is, therefore, the first in the chain.

But what is the cause of this ascending current of air?

I am not aware that any of the writers mentioned in the lecture attempt to account rationally for the ascending current, except by attributing it to the effect of the heat of the sun's rays acting upon a cloud.

These rays penetrate dry air without heating it very much, but they will warm up and expand a cloud, which then will rise, but very slowly.

If any one from an elevation, in the morning, watch the clouds, which have been roosting over night in the valleys, slowly ascend to their places during the day, he will find their ascentional motion so slow as to be scarcely perceptible, so weak is the draft of "the chimney without walls."

Dr. Robert Hare, Professor of Chemistry in the University of Pennsylvania, offered an explanation*, which, though apparently not accepted by the scientific world, is still so consonant with many unexplained phenomena that it would be well to reconsider it.

Referring the reader to Dr. Hare's papers on the subject for a more exact statement of his views, I will briefly repeat the substance of conversations had with him over thirty-five years ago. He said: "There are two familiar experiments in the lecture room, illustrating two different methods of electrical discharge. (1) The electric spark, called the disruptive discharge, and, (2), the pith-ball experiment, which is one method of the convective discharge.

"These are small illustrations of electrical discharges which both occur on a grand scale in nature. Dr. Franklin identified the electric spark with the lightning, and that is conceded. Now a convective discharge on a grand scale in nature takes place when atmospheric air, mingled with the vapor of water, under appropriate electrical conditions, is

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* "On the Causes of the Tornado or Water Spout." By R. Hare, M. D., etc. *Transactions of the American Philosophical Society.* New Series, vol 5, pp. 375–384. Read before the Society April 2, 1836.

Published also in :

Silliman's Journal. Vol. 32, pp. 153–161, July, 1837.

Bibliographie Universelle. xi, pp. 156–159, 1837.

Froriep Notizen. iv, col., 257–259, 1838.

Quetelet. *Corresp. Mathematique.* x, pp. 110–113, 1838.

Sturgeon. *Annals of Electricity.* ii, pp. 195–203, 1838.

See also :

Transactions Am. Phil. Soc. Vol. vi, pp. 297–302, 1839.

Silliman's Journal. xxxviii, pp. 73–86, 1840.

Sturgeon. *Annals of Electricity.* iv, pp. 393–396, 1839–1840.

repelled from the earth and projected upwards with great violence. This is the ascending current of air and vapor in the middle of the tornado. The air rushes in from every direction to restore the equilibrium, and acquires a rotary motion. Here we have an adequate cause for the violence of the tornado, which could never be derived immediately from the heat of the sun. No doubt the sun's heat, acting over large areas, is the cause of the trade winds, but directly it could never produce so local and so violent a disturbance as the tornado."

No doubt an exact analogy between the pith-ball experiment and the alleged convective discharge in nature would require us to provide an upper plate. But convection discharges take place without this in the lecture room.

Dr. Hare's opinions upon this subject were authority with me, but a subsequent observation of my own convinced me completely of the existence of the convective discharge in nature on a grand scale and of its predominating influence on meteorology.

Upon the 30th of April, 1856, I was travelling in the diligence from Florence to Bologna, Italy. We had descended from the hills into the southern margin of the great plain of Lombardy, and at 5 o'clock in the afternoon we were about two hours distant from Bologna. The day had been calm and serene. The sun was declined below the spurs of the Apennines to the west, but his rays illuminated a dense black cloud far to the eastward. The base of this cloud, was below the visible horizon and it seemed to rest upon the earth. It appeared to cover about a mile of the earth's surface and was two or three times as high as broad. There was no appearance of wind motion about the cloud, which was an irregular oblong in apparent shape, resting on the smaller end. My attention was first attracted to the vivid lightning, which was incessantly playing through the cloud.

While watching the lightning, I was amazed to see, suddenly, the middle portion (say about one-fourth) of the side of the cloud towards me projected vertically with incredible velocity, pushing through the whole cloud from base to summit.

It appeared like smoke rushing from the mouth of a cannon, of over a thousand feet calibre, fired vertically.

The lightning ceased immediately. The ascending current in the cloud continued for a considerable time, gradually diminishing in velocity. The motion was distinctly visible, for the moving part of the cloud was shaded differently from the rest, which showed no movement. This different appearance was possibly due to dust or other foreign matter entrained in the movement.

As soon as I could recover myself, I estimated the time occupied by a recognizable portion of the ascending column in moving from the base to the summit of the great cloud, and made it three seconds by my pulse.

Now all these figures are merely estimates. Assuming them to be correct, the upward motion of the column had a velocity of from two-thirds of a mile to one mile per second. The ascending column, as it issued just above the great cloud, seemed to have passed its goal and lost its volume and velocity. What was left of it was much lighter in color and fleecy in appearance. It floated off lazily in fragments to the right and left, and when clear of the great cloud it rapidly descended towards the earth, and then moved towards the base of the great cloud and joined to it. This indicated an outblowing current of air above, and an inblowing below.

Upon arrival at Bologna, while the baggage was being examined, I stepped outside the gates to take a last view of the scene of the late storm. The great cloud was scattered, the higher portions reflecting the rays of the sun, now set. There was an icy-cold wind blowing *from* the direction of the late disturbance.

When I arrived at the hotel I called the landlord, and told him I wanted to go the next day to a place about fifteen miles southeast of Bologna, where I had observed an electrical storm of a peculiar character about three hours before. He told me that the next day was market day, that he had many customers living in that direction, and that if I only wanted to know the character of the storm he could probably get the information from some of them, and he

promised to make inquiries. I assented and waited. The next day, after a tour of sight-seeing, I returned to the hotel and asked my landlord if he had made the inquiries he had promised. He answered that there was no necessity for asking questions. All the men who came in from that district were full of their accounts of the greatest *hailstorm* they ever saw, and could talk of nothing else.

I have said that the eruption appeared at the middle of the western side of the cloud presented to me. Had it taken place within the cloud, I could not have seen anything except the slight disturbance over the summit, such as has been observed before, and attributed to a violent ascending current. The rays of the sun must have warmed the western face of the cloud and caused some circulation, but this would appear to have had only a similar relation to the great uprising, as the burning of the fuse of a cannon has to the subsequent explosion.

The *rationale* of this hailstorm seems to be very simple. The vapor projected upwards to above the snow line, condensed and froze to small hailstones, which would be impelled to fall by gravity, but could not fall against the current. They were kept dancing upon the vertical blast, growing larger all the time, until some of them would be jostled overboard, or, until the cessation of the blast permitted them to fall *en masse*.

But why did not the summit of the great cloud (assumed to be above the snow line) condense before the great upblast from the lower part? Perhaps portions of it did, for the lightning was brilliant and frequent.

The experiments of Dufour* may throw light upon the subject.

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* *Bibliographie Universelle*, 1861. *Annales de Chim. et de Phys.*, iii, 68, pp. 370-393.

Dufour says, with philosophical caution: "Il me parait hors de doute que la chaleur seule, agissant sur ce corps sans le concours d'actions moleculaires étrangères, ne peut pas produire son changement d'etat que bien au dessus de la temperature envisagée comme celle de l'ebullition normale."

And also:

"Les retards d'ebullition sont manifestment du même genre que les retards de solidification."

In the experiment upon the feezing of water floating in a suitable bath of oil, which was gradually cooled, he found that the larger globules were generally the first to freeze, the smaller ones remained fluid longer, and some of them of one millimetre diameter survived in a liquid state until the temperature of the bath was reduced to —20° C. A larger globule, frozen at —1° to —2°, being pushed against a globule of water, the water would flow around and envelop the frozen globule and freeze over it, and this could be repeated over and over again, thus imitating artificially the concentric layers of a hailstone.

Operating in the same way upon water within a bath of oil, which was gradually heated up, he found, as a rule, that the larger globules first became steam, while the smaller remained as water, and some globules of from one to three millimetres diameter, remained liquid until the bath was heated to 175° to 178° C. under atmospheric pressure. Steam at this temperature has an elastic force of eight or nine atmospheres.

A light galvanic current passed through a globule always and immediately caused it to become vapor.

The conditions under which Dufour obtained his extreme results were: (1) Very small globules of water; (2) quiet; (3) absence of contact with solid bodies, and (4) electrical insulation. All of these conditions probably existed at the summit of the cloud, the size of the globules of water in the cloud being very much less. It is, therefore, reasonable to suppose that condensation and freezing there could not have taken place even at an extremely low temperature. Dufour reports no experiments upon cloud, but the mutual repulsion among the particles of a highly electrified cloud would alone probably delay aggregation.

The violent projection of the lower part of the cloud, charged with the electricity of the earth and conveying solid matter to the cold regions above, would destroy all the conditions of delay and occasion immediate condensation and freezing.

It would appear from the foregoing considerations that the difficulties which Pouillet has presented in understanding

hailstorms have disappeared in this case.* He says: "To explain hail, there are only two difficulties, but they are very great, and we can say in advance that they remain above all the efforts which have been made to resolve them.

"In the first place, the thing is to know how the cold is produced which freezes the water, and then, how is it that a hailstone which has acquired size enough to fall by its own weight rests still suspended in the air during all the time which is necessary for it to arrive at a volume of from twenty to thirty centimetres of circumference (eight to twelve inches)."

I am not aware that any account of an ascending current of such velocity and violence as that described, has ever been published. Generally the existence and character of such currents have been proved only by their disastrous results. Such proofs, however, are innumerable and overwhelming. The ninth edition of the *Encyclopædia Britannica* contains, for instance, a description of a storm at Mt. Carmel, Ill., June 4, 1877, by which the Methodist Church steeple, with its ball and vane, was carried off bodily through the air fifteen miles to the northeast. The ascensional force exhibited in this and many other instances must have required an incredible vertical velocity of wind.

Let us suppose a great cloud (which is no better conductor of electricity then dry air) highly charged with, say, positive electricity, to be floating in an atmosphere similarly electrified and resting over a portion of the earth's surface largely charged with negative electricity by induction. The cloud would be attracted until it touched the surface of the earth, already warmed by the sun. The particles of cloud in contact, after acquiring a negative charge, would be repelled from the earth to the lower surface of the positive cloud, where they would join to and neutralize a similar quantity of cloud and both be repelled to and from the cloud and the earth alternately, increasing in volume and range until the character of the convection should change

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* Pouillet. *Elements de Physique et de Meteorologie. De la grêle, etc., liv, viii.*

to a dark glow of immense proportions accompanied by a violent wind, terminating as seen.

If these violent vertical currents are not occasioned by convectional discharges of electricity, as Dr. Hare supposed them to be, what are the causes of them? Their existence is certain, and indeed it is probable, that they frequently occur, not with violence and destruction, but with gentle action and beneficent effects upon the temperature of the lower atmosphere. We shall have to classify them and give them Greek names and call it "science," according to the rule of the old peripatetic: "*Qu'il faut bien citer ce qu'on ne comprend point de tout dans la langue qu'on entends le moins.*"

THE DIFFRACTION OF SOUND.

BY W. LE CONTE STEVENS.

[*Abstract of a Lecture delivered before the* FRANKLIN INSTITUTE, *February 18, 1889.*]

The conception that sound is due to wave motion in an elastic material medium seems to have been entertained before the beginning of the seventeenth century by Lord Bacon. To Sir Isaac Newton, however, is due the credit of formulating it distinctly, and establishing it firmly on a mathematical basis. The application of the same theory to light was most natural, but Newton's clear understanding of certain necessary consequences, which, to his mind, did not seem to be realized in the case of light, caused him to reject the wave theory and to substitute for it his well-known emission theory, which for more than a century held undisputed sway. The phenomena of diffraction, which constituted Newton's stumbling-block, became afterward the strongest evidence in favor of the wave theory of light as developed by Young and Fresnel. The elementary experiments had been repeated by Grimaldi, Hooke, Huygens and Newton, but the true explanation of them did not occur to a single one of these acute observers. Waves of

light were not too short for Newton to measure, but instead of regarding them as waves, he measured what he took to be the intervals between "fits" of reflection and of transmission.

If we admit the fundamental principles of the wave theory as developed by Huygens, it follows as a necessary consequence that diffraction must occur at the edges of any obstacle interposed in the path of a wave front, or at the edges of one or more openings through which the waves are propagated. With a view to application, it may be advisable to give briefly the deduction of the formula for interference by waves diffracted at the edges of small openings.

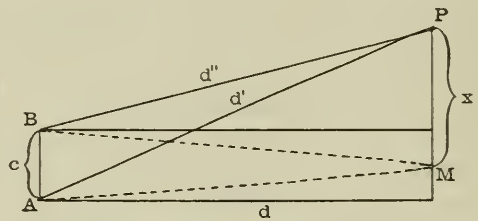


FIG. 1.

Let A and B be edges of a pair of contiguous minute openings through which waves are propagated in the same phase; they become centres therefore of new systems of secondary waves. Let AM and BM be the sides of an isosceles triangle with AB as base. Then M is a point where like phases meet, a point of maximum motion: of brightness if the waves be those of light, of noise if they be those of sound. Through M let a plane be passed perpendicularly across the original direction of propagation, and let P be any point of it. For brevity the distance from A or B to this plane may be called d; from A to P, d'; from B to P, d''; from A to B, c; from M to P, x, and the wave length, λ. Then, if $d' - d'' = \lambda$, or $d' - d'' = n\lambda$, n being any integer, P is a point where like phases meet, and therefore a point of motion. If $d' - d'' = \frac{1}{2}\lambda$, or $d' - d'' = \frac{1}{2}n\lambda$, P is a point where opposite phases meet, and therefore one

of quiescence. To find the distance, x, between two successive points of maximum motion, we have

$$d'^2 = d^2 + (x + \tfrac{1}{2}\,c)^2$$

$$d''^2 = d^2 + (x - \tfrac{1}{2}\,c)^2$$

Extracting the square root and discarding powers of c, since this is small in comparison with d, as is x also, we have, approximately,

$$d' = d + \frac{(x + \frac{1}{2}\,c)^2}{2\,d}$$

$$d'' = d + \frac{(x - \frac{1}{2}\,c)^2}{2\,d}$$

whence,

$$d' - d'' = \frac{c}{d}\,x$$

but

$$d' - d'' = \lambda$$

hence,

$$x = \frac{d}{c}\,\lambda$$

From this well-known formula it is seen that $x \propto \lambda$. If c be the element of a diffraction grating for light, and d be the distance from grating to screen, x is at once determined if λ be known. Assuming a coarse transmission grating in which $c = \frac{1}{1250}$ inch, taking λ for red light $= \frac{1}{40000}$ inch, and $d = 300$ inches, we have the value of x a little over nine inches.

Now assuming the waves to be those of sound, the pitch being that of a high soprano tone, 1,024 vibrations per second, if diffraction could be produced and measured from such a grating, the corresponding value of x would be not far from eighty miles. Increasing the element of the grating to an inch, x is reduced to about 10 drayos. It is obvious, therefore, that the diffraction of sound waves is, under ordinary conditions, so great as to defeat all efforts directed toward its actual measurement or even qualitative demonstration. Sound shadows, instead of being nearly geometric like those of light, are usually too ill-defined to be traceable at all, if the propagation is through air.

In 1826, Colladon's classic experiments were made in the Lake of Geneva for the determination of the velocity of sound in water. Incidentally he noticed quite well-defined sound shadows behind the edge of a stone wall projecting into the lake. A peculiar phenomenon, which was observed but not explained by him, was that the sound of the distant bell reached the membrane of the submerged hearing trumpet as a sharp click, without definite musical character. This was due to the quick and violent initial stroke of the hammer upon the bell, while the energy of the slower vibrations, due to the bell's elasticity, was absorbed by the aqueous medium.

In 1874, much more remarkable experiments on the production of sound shadows in water were made in the Bay of San Francisco, by Prof. John Le Conte and his son, Mr. Julian Le Conte. In the process of deepening the harbor, dynamite was used for the purpose of blasting away a submerged reef of sandstone. Glass bottles hung in the water were shattered by the impulse propagated through the elastic medium from a distance of forty feet, but perfectly protected if placed within the geometric shadow of a pile. When the cartridge was aligned with two piles twelve feet apart, forty feet from the nearer one, the well-defined shadow of the first pile covered the second one, so that bottles placed anywhere between the two were protected. Thick glass tubes, placed across the shadow, were shattered in all parts exposed beyond it, and protected in the middle parts that were within it.

To account for the comparative absence of diffractive effects in these experiments it is necessary to assume that the waves were exceedingly short. It was pointed out by Dr. Le Conte that a sufficient cause for this is found in the instantaneous character of the dynamite explosion. The wave length is equal to the product of the velocity of propagation and the time consumed in generating the wave. This form of statement is only a modification of the familiar formula,

$$\lambda = \frac{v}{n}$$

since the time of a single vibration and the number of

vibrations per second bear a reciprocal relation. The quickness of action manifested in the explosion of dynamite is such that the duration of the generating impulse is almost infinitesimal. Assuming it to be a millionth of a second, and taking $v = 4{,}700$ feet for water, the resulting wave length would be only about one-seventeenth of an inch.

In 1880, the explosion of a dynamite factory near the University of California resulted in the production of two sounds at a distance, one conducted by the ground, the other by the air. The university building cast an acoustic shadow, at least three hundred yards long, within which the aërial impulse was imperceptible. The velocity of sound in air being less than a fourth of that in water, the wave length under similar conditions must be correspondingly short.

Prior to the dynamite explosion just mentioned, Lord Rayleigh, in England, had achieved some remarkable results in diffraction of sound, without resorting to so dangerous a source as an explosive. A whistle of very high pitch was employed as a producer of sound. The difficulty in using it consists in the fact that when the intensity is very slight a high pitch becomes inaudible. Something else than the human ear has to be used, therefore, as an appreciator or indicator. Dr. Le Conte discovered in 1857 that, under appropriate conditions, a common gas flame is delicately sensitive to sound. In the hands of Barrett and Tyndall the sensitive flame was improved; and Lord Rayleigh has employed it in exploring the regions of the air, where, according to theory, sound shadows ought to be produced when short waves are propagated from a source, such as the whistle just described. I have repeated successfully all the experiments described by Lord Rayleigh, many of which have been but recently devised, and I have used the sensitive flame in establishing still further analogies between light and sound.

The value of a good sensitive flame may be illustrated in a variety of ways. In producing it the cylindrical steatite burner is best fitted into the end of a metal pipe, which is connected by rubber tubing with a cylinder of compressed coal gas. From this the supply of gas is care-

fully regulated with the aid of a water manometer gauge. A good burner gives a tall quiet flame, twenty inches or more in height, which does not begin to flare until the pressure is in the neighborhood of ten inches of water. When just ready to flare, but still quiescent, such a flame indicates very beautifully the ticking of a watch held near it, every tick producing a momentary disturbance of the flame which is visible across a large audience room. It is, moreover, unequally sensitive in two directions at right angles to each other, as first pointed out by Lord Rayleigh. If the pressure be adjusted so that the flame just flares when its sensitive side is turned toward the high pitched whistle, it will cease to flare when turned round on its own axis through a right angle, so that its "deaf" side is toward the whistle. Let a mirror now be placed a foot away on the sensitive side, and equally inclined to flame and whistle. The flaring is at once renewed, but ceases the moment the angle of incidence is changed by rotating the mirror slightly about a vertical axis. Restoring the flame so that its sensitive side is again toward the whistle, if the mirror is put on the further side squarely across the line of direction of the whistle, the flame is seen alternately to flare and become quiescent according to the distance at which the mirror is held. Reflected waves meet advancing waves, producing loops and nodes. If the mirror is at such a distance that the flame is in a loop, it flares with much violence; if in a node, it becomes quiescent. Lord Rayleigh made the remarkable observation that the effect on the ear is just the reverse. The sound seems most intense when the ear is at a node rather than a loop. A convenient method is at once suggested for measuring the pitch of the whistle, even though the note it yields may be too faint and too high to be distinctly audible. By carefully measuring the distance between two successive positions of the mirror which cause the flame to be in a node, the half-wave length is obtained. The pitch thus becomes known from the formula,

$$n = \frac{v}{\lambda}$$

where v is the known velocity of sound, and n is the number

of double vibrations per second. For these experiments the whistle should yield from 12,000 to 24,000 as its pitch.

The most interesting application of the sensitive flame is in relation to the phenomena of sound shadows and diffraction. The whistle may be held in a fixed position, and supplied with a constant blast by connecting it with a cylinder of compressed air, the supply being regulated with a water manometer gauge. When the sensitiveness of the flame is so adjusted that it flares distinctly though not very violently, the interposition of the hand is enough to restore it to quiescence by protecting it with a sound shadow. A circular disk of card-board may be substituted for the hand. In one position it may serve as a protector. In another it may cause the flame to flare as strongly as if no obstacle existed. This is caused by the meeting of waves diffracted at the edges of the disk so as to meet at a point behind the middle of this. The experiment was first performed by Lord Rayleigh about 1878; it is the acoustic analogue of the celebrated experiment in diffraction of light, skeptically suggested by Poisson and performed by Arago immediately after the French Academy had received Poisson's adverse criticism of Fresnel's paper on diffraction, written in 1819.

This principle is conveniently applied to the construction of a diffraction grating for sound, such as was first made by Lord Rayleigh. Let A (*Fig. 2*) be the radiant point, the mouth of the whistle. Let B be the sensitive point, the opening of the steatite burner at the end of the nozzle. Let a plane be passed perpendicularly across the line AB at some point, O. Every point in this plane may, according to Huygens' principle, be regarded as a diffractive centre from which secondary waves are sent forth. Let P be one of these points so selected that the sum of the distances AP and PB shall exceed AB by a half wave length; or using symbolic notation,

$$(a' + b') - (a + b) = \tfrac{1}{2}\,\lambda \tag{1}$$

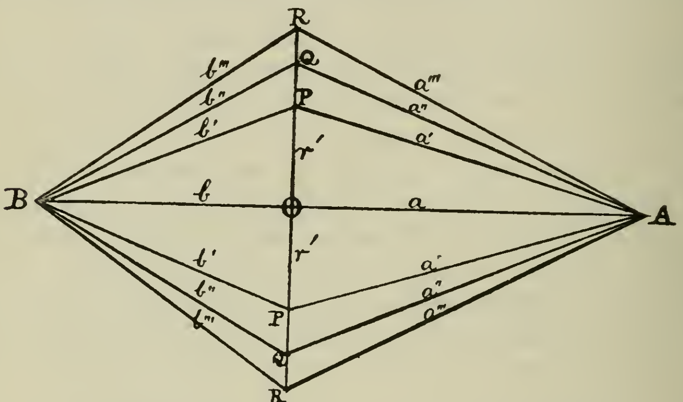
Then the diffractive effect of P is to produce at B complete interference with waves proceeding from A directly to B.

In like manner there exist other points, Q, R, etc., so placed that

$$(a'' + b'') - (a + b) = \tfrac{2}{2}\lambda \qquad (2)$$

$$(a''' + b''') - (a + b) = \tfrac{3}{2}\lambda, \text{ etc.} \qquad (3)$$

From this it is seen that if OP, OQ, OR, etc., be taken as radii, and circumferences be drawn in the transverse plane, we will have a central circle and concentric rings around it so related that for every point in the circle whose radius is OP there is a point in the adjacent ring whose width is PQ, the effect of which is to produce complete interference; and one in the alternate ring whose width is QR, the effect of which is to produce complete accordance.



$OP = r'$; $OQ = r''$; $OR = r'''$; λ = wave length.

FIG. 2.

Let the radii OP, OQ, OR, etc., be called r', r'', r''', etc. Then

$$a'^2 = a^2 + r'^2, \therefore a' = (a^2 + r'^2)^{\frac{1}{2}} \qquad (4)$$

$$b'^2 = b^2 + r'^2, \therefore b' = (b^2 + r'^2)^{\frac{1}{2}} \qquad (5)$$

Expanding (4) and (5) by the binominal theorem, and rejecting all after the second term, since r' is small in comparison with a or b, we have, approximately,

$$a' = a + \frac{r'}{2a}$$

$$b' = b + \frac{r'}{2b}$$

In like manner,

$$a'' = a + \frac{r''}{2a}$$

$$b'' = b + \frac{r''}{2b}, \text{ etc.}$$

Substituting these values of a' and b' in equation (1), also of a'' and b'' in equation (2), etc., and reducing, we have

$$r'^2 = \frac{ab}{a+b}\lambda$$

$$r''^2 = \frac{ab}{a+b}2\lambda$$

$$r'''^2 = \frac{ab}{a+b}3\lambda$$

Or, if n represent the order of any zone whatever,

$$r_n^2 = \frac{ab}{a+b}n\lambda$$

If the position of the plane of zones be midway between A and B, this formula becomes

$$r_n^2 = \tfrac{1}{2}an\lambda$$

The value of λ for any given whistle having been determined by the method of stationary waves just described, and that of a being selected at will, the successive values of r are found, and the corresponding circles drawn on cardboard or zinc. Leaving the central circle intact, the first, third, fifth, etc., rings are cut out. The diffractive effects of all the remaining alternate zones are therefore conjoined, and a flame at B flares now far more violently when the whistle is sounded than if no obstacle had been interposed. If the grating be slightly lifted so as to throw the axial line AB above the nozzle of the burner, the flame becomes quiescent. It was previously in a region of noise; it is now in a ring of silence that surrounds it. Lifting the grating a little higher, the flame flares again slightly; it is in a ring of noise. This is roughly shown in *Fig. 3*, which is an amplification of the left half of *Fig. 2*. It is seen that there are other points, C, D, etc., at which sound rays from the

diffractive centres P, Q, R, etc., may meet, though the conjoint effect may not be so strong as at B. The locus of C is obviously a circle around B as centre. The relative intensities of disturbance are shown by the black areas, as determined by the German physicist, Lommel. I have at times succeeded in tracing out four or five of these successive rings of noise and silence by the aid of the sensitive flame.

When light is transmitted through a pair of adjacent small apertures, diffraction fringes are produced. According to theory, as shown by Young and Fresnel, the locus of

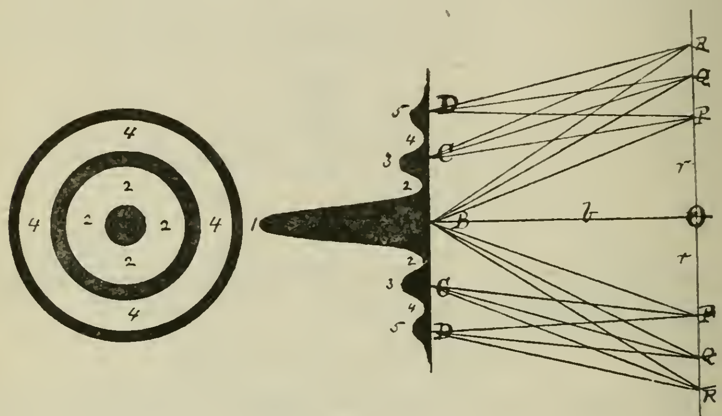


FIG. 3.

At 1, 3 and 5, meeting of like phases.

At 2 and 4, etc., meeting of unlike phases.

1, central area of noise; 2 and 4, first two rings of silence; 3 and 5, first two rings of noise.

interference in space between aperture and screen is a hyperbola. By very delicate micrometric measurements Fresnel found the results of experiment to justify the prevision of theory. I have applied the sensitive flame in exploring for these hyperbolas when short sound waves were transmitted through a pair of openings in a screen of cardboard. The whistle, whose pitch was about 13,000, sent forth waves, therefore, of about 1·05 inch in length. It was placed thirty-four inches from the screen, whose width was two feet. Near the middle of this were cut two vertical

slits, three inches apart and one-quarter inch wide. The screen being at right angles to the line of direction of the whistle, and this line passing midway between the two slits, the position required by theory for the hyperbolic bands was determined. There was no difficulty in detecting the middle line of maximum motion behind the screen. The nearest hyperbolas on the two sides of this were then found and traced back about a foot. The definition of these was inferior to that of the middle line, as might naturally be expected. The next pair of hyperbolas was also found, but with poor definition.

Perhaps the most important experiment employed by Fresnel in the establishment of the wave theory of light was that of producing interference bands, independently of all diffracting edges, by reflecting the light from a pair

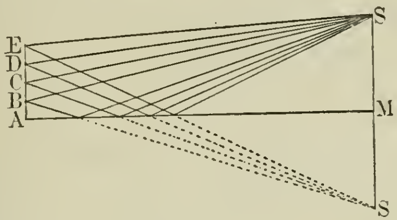


Fig. 4.

of mirrors making with each other an angle of very nearly 180°. The acoustic analogue of this has been performed by Prof. A. M. Mayer and myself together. Six interference bands were detected by means of the sensitive flame. Their distance apart was measured, and the result was found to accord very closely with that demanded by theory. On account of the trouble resulting from waves proceeding directly from the source of sound, or diffracted around the edges of a screen interposed to cut them off, this method of experiment was abandoned. A modification of the experiment was repeatedly tried by me, and with quite uniformly satisfactory results. A single mirror was placed horizontally on the table, so that waves reflected from it might interfere with those proceeding directly from whistle to flame. The effect of the reflected waves was the same as

if they had come from a virtual source, S' (*Fig. 4*), and the theory becomes then the same practically as that given on a previous page for the diffraction grating for light. Knowing λ, AM, and SM, and the distances AB, AC, AD, etc., at B, C, D, etc., there is complete accordance; or, the distance of the points of complete interference may be measured and the results of experiment compared with those of theory.

In the following table the results of some experiments are given. The height, MS, of whistle above table is ten inches; the distance AM, thirty-six inches; the wave length λ, 1·05 inch. Then

$$AB = \frac{AM}{SS'} \lambda$$

The successive measurements are of distances above the table at which the flame became quiescent. The first column is calculated from the formula; the others are the records from five sets of experiments.

Theory.	I.	II.	III.	IV.	V.
·945	·9	1·0	·9	1·0	1·0
2·835	2·8	2·7	2·7	2·8	2·9
4·725	4·7	4·6	4·7	4·9	4·7
6·615	6·7	6·7	6·7	6·9	6·7
8·505	8·9	9·0	8·8	9·0	9·1
10·395	11·0	11·3	11·0	11·2	11·3
12·285	—	13·6	—	13·6	13·6

These results are sufficient to show that the sensitive flame makes it possible to exhibit before large audiences the demonstration of principles hitherto accepted as the result of calculation, or verified only by individual experiment. If not applicable for purposes of refined and exact measurement, it comes nearer to the fulfilment of these conditions than any other means that has hitherto been applied for these purposes in acoustics.

PROCEEDINGS

OF THE

CHEMICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Stated Meeting, held at the* INSTITUTE, *Tuesday, May 21, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 21, 1889.

Mr. H. PEMBERTON, Jr., President, in the Chair.

Members present: Mr. Chas. Bullock, Prof. R. L. Chase, Dr. W. C. Day, Mr. Lee K. Frankel, Dr. Wm. H. Greene, Mr. Reuben Haines, Dr. L. B. Hall, Dr. S. C. Hooker. Mr. Fred. E. Ives, Dr. H. W. Jayne, Dr. H. F. Keller, Mr. T. C. Palmer, Mr. W. L. Rowland, Prof. S. P. Sadtler, Dr. E. F. Smith, Prof. Henry Trimble, Dr. Wm. H. Wahl.

Dr. Greene called the attention of the Section to the fact that efforts are now being made by the American Association for the Advancement of Science to form a National Chemical Society, with headquarters in Washington, and which shall hold regular annual meetings. He further stated that he had been requested by a member of the American Association to bring the matter before the Chemical Section of the INSTITUTE, with the object of securing the nomination of delegates to represent the Section in the matter at a meeting to be held at the same time and place with that of the American Association, to be held during the coming summer.

After some discussion by the President and Drs. Hall, Wahl and Greene, on motion of Dr. Greene, it was voted that the President appoint a committee to investigate the matter more fully, and report to the Section at its next meeting. The President appointed Drs. Greene, Hall and Wahl members of this committee.

Professor Sadtler then read a paper, "On the Presence of Paraffine in Crude Petroleum," which was referred for publication.

Mr. Charles Bullock read a paper "On the Preparation and Properties of Pure Metallic Manganese." He also exhibited two specimens of metallic manganese; one of them had been obtained by reducing chloride of manganese by means of sodium, using fluor spar alone as the flux, and the other by using chloride of sodium without fluor spar. The paper was referred for publication.

Dr. Keller followed with a paper "On Kobellite from Colorado, and the Chemical Composition of this Mineral;" also, "An Analysis of Megabasite." Some very fine specimens of the minerals were exhibited by Dr. Keller. The paper was submitted for publication.

Dr. Hooker then read his report "On the Philadelphia Water Supply" for the past month. Aside from the muddiness of the water, the report was favorable to the present condition of the supply. The report was submitted for publication.

A paper "On the Electrolytic Separation of Cadmium from Zinc," by Dr. Smith and Mr. Frankel, was next read by Dr. Smith. It was submitted for publication.

Dr. Smith also read a paper entitled, "Derivatives Obtained from Mono-Chlor-Dinitro-Phenol and Bases of the Aromatic Series."

This paper is preliminary to an investigation now going on. It was referred for publication.

Dr. Greene then followed with recent results obtained by him and Dr. Hooker in their investigation of lapachic acid and its derivatives.

Upon recommendation of the President and motion of Mr. Palmer, it was voted that the notification of members of the meetings of the Section be attended to, under the direction of Dr. Wahl, by one of the clerical force of the INSTITUTE.

Adjourned. WM. C. DAY, *Secretary.*

A RAPID COLORIMETRIC METHOD OF DETERMINING NITRATES IN POTABLE WATERS.*

By Samuel C. Hooker, Ph.D.

[*Read at the Stated Meeting of the Chemical Section of the* Franklin Institute, *March 19, 1889.*]

In devising a process for the estimation of nitrates in the minute quantities in which they occur in natural waters, I have not been ignorant of the fact that there are already several very satisfactory ways in which this can be accurately done. I have, however, aimed at greater rapidity than has heretofore been possible.

Fully fifteen years ago Graebe and Glaser discovered carbazol, and observed that when dissolved in concentrated sulphuric acid it gave rise to an intensely green solution on the addition of nitric acid. This reaction, which up to the present time has been used only as a means of identifying carbazol, forms the basis of the process to be described. Its extraordinary delicacy renders it particularly suitable for the purposes of water analysis, and enables a quantity of nitric acid, containing as little as $\frac{6}{10,000}$ of a milligramme of N to be accurately determined. The reaction is not, however, peculiar to nitric acid; all oxidizing agents behave similarly. Graebe and Glaser enumerate chlorine, bromine, iodine, nitrous and chromic acids as giving rise to the same intensely colored solution. With the exception of nitrous acid, the substances just mentioned are almost invariably absent from natural waters, and may therefore be dismissed from further consideration. There is, however, one other oxidizing agent, namely iron in the ferric condition, which is sometimes found in very appreciable quantities, and it therefore became necessary, in studying the influence of the substances in solution upon the process, to give special attention to iron as well as to nitrous acid.

* See preliminary paper, Journal of the Franklin Institute, **127**, 16.

As the result of a number of careful experiments, the following conclusions were arrived at with regard to the application of the process:

(1) No material error will arise in the presence of nitrites in the quantities in which they usually occur.

(2) Iron (in the ferrous or ferric condition), if present in quantities greater than 0·1 parts per 100,000, must be removed.

(3) Chlorides, even when present in very small quantities, must be removed.

(4) Carbonate of lime, sulphates of lime, soda, etc., in the quantities in which they ordinarily occur, were not found to influence the determinations.

(5) The presence of easily destructible organic matter, such as albumen, lowers the result, not materially, however, unless present in large excess.

The estimation, briefly described, is made as follows:

Two cubic centimetres of the water to be examined is mixed with 4 cc. concentrated sulphuric acid; the mixture is cooled and a small quantity of carbazol, dissolved in sulphuric acid, added. If nitric acid be present, the solution will turn green on the addition of the carbazol, and the intensity of the color, by comparison with that produced by solutions of potassic nitrate of known strength, will, within certain limits, indicate the amount of the acid present.

The great majority of waters can be estimated directly without previous concentration, and only a few will need to be diluted. The limits within which the determinations may be safely made are marked by quantities of nitric acid representing ·03 and ·40 parts N per 100,000. Water containing either less or more nitric acid than indicated by these figures must be concentrated or diluted.

To test the accuracy of the process, a number of solutions were prepared, at my request, containing different quantities of potassic nitrate. In order that my judgment might not be influenced by a knowledge of the amount of nitric acid present, I was kept in ignorance of the strength of the solutions until after the estimations had been completed.

The following are the results obtained:

NITRIC ACID EXPRESSED AS N IN PARTS PER 100,000.

Present.	*Found.*	*Error.*
·127	·130	+ ·003
·078	·075	— ·003
·200	·190	— ·010
·302	·300	— ·002
·290	·290	·000
Average error, ...		·0036

NITRIC ACID PRESENT IN THE 2 CC. OF WATER OPERATED UPON EXPRESSED IN DECIMALS OF A GRAMME.

Present.	*Found.*	*Error.*
·00001143	·00001170	·00000027
·00000702	·00000675	·00000027
·00001800	·00001710	·00000090
·00002718	·00002700	·00000018
·00002610	·00002610	·00000000
Average error, ...		·000000324

The above results are not selected, but include all the determinations that have been made with solutions of unknown strength, with the object of testing the delicacy of the process. It is to be borne in mind, that potassic nitrate *only* was present. Considering the extremely minute quantities operated upon, the accuracy of the above results is very noteworthy.

The following reagents are required :

(1) Concentrated sulphuric acid.
(2) An acetic acid solution of carbazol.
(3) A sulphuric acid solution of carbazol.
(4) Standard solutions of potassic nitrate.
(5) A solution of aluminic sulphate.
(6) A standard solution of sulphate of silver.

(1) The sulphuric acid, used for all purposes in the process, should be almost entirely free from oxides of nitrogen. It may be readily tested by dissolving in it a small quantity of carbazol. If the solution be at first golden yellow or brown, the acid is sufficiently pure ; if it be green or greenish, another and better sample must be taken. It is essential also that the specific gravity of the acid be fully 1·84,

and it is well to ascertain that this is really the case, as I have found several samples, obtained from sources which are generally thought reliable, to fall considerably below these figures. The acid was in fact worthless for the purpose required.

(2) The carbazol used was obtained from Kahlbaum,* of Berlin. The acetic acid solution is prepared by dissolving 0·6 gramme in about 90 cc. of 99–100 per cent. acetic acid, by the aid of gentle heat. It is allowed to cool and is then made up to 100 cc. by the further addition of acetic acid. The exact strength of this solution is of no material importance to the success of the process, and the above proportions have been selected principally because they are convenient. The solution will probably remain unchanged almost indefinitely; but I cannot speak positively in this respect, as my actual experience extends only over a period of several months. The use of this solution merely facilitates the preparation of that next described, which will not keep, and has consequently to be freshly prepared for each series of determinations.

(3) The sulphuric acid solution of carbazol is easily made in a few seconds, but it is advisable to allow it to stand from one and one-half to two hours before using. It is prepared by rapidly adding 15 cc. of sulphuric acid to 1 cc. of the above described acetic-acid solution. This quantity usually suffices in my hands for from two to three nitrate estimations. When freshly prepared it is golden yellow or brown; it changes gradually, however, and in the course of one and one-half or two hours it becomes olive-green. I am not able to say positively to what this change is due, but it seems probable that traces of oxidizing agents occur in the sulphuric and acetic acids, and that these, although not present in sufficient quantity to act immediately, gradually bring about the reaction described. The greenish color does not interfere with the process, as might at first be supposed; on the contrary, I have observed that the solution is not sensitive to small quantities of nitric acid until

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* Kahlbaum's carbazol may be obtained from James W. Queen & Co., Philadelphia.

it has undergone the change to olive-green, and it is for this reason that I have advised that it should be prepared about two hours before required for use. This solution may be thoroughly depended on for six hours after preparation. The intensities of color produced by the more concentrated solutions of nitrates after this time, gradually approach to each other and become ultimately the same.

(4) The standard solutions of potassic nitrate are very readily prepared. The solutions which are to be compared directly with the waters examined, may be prepared as required, but if many determinations are to be made with a variety of waters, it will be found best to prepare a complete series, differing from each other by ·02 parts N in 100,000. This series may include solutions containing quantities of nitrogen in 100,000 parts, represented by all the odd numbers from ·03 up to ·39. It will be found convenient to prepare them in quantities of 100 cc. at a time, from a stock solution of potassic nitrate (b), which contains ·00001 gramme N, or ·000045 HNO_3 in 1 cc. Each cubic centimetre of this solution, when diluted to 100 cc., represents ·01 N in 100,000, and consequently if it is desired to make a solution containing ·35 parts N in 100,000, 35 cc. are taken and made up to 100 cc., and so on. The solution of potassic nitrate (b) is best prepared from a stronger one (a), containing ·0001 gramme N to the cubic centimetre, or ·7214 gramme KNO_3 to the litre: 100 cc. of (a) made up to one litre, gives the solution (b). It is obvious that the series of solutions above described could be made directly from (a), but by first making (b) greater accuracy is secured.

(5) For purposes which will be presently described, a solution of aluminic sulphate is required, containing five grammes to the litre. The salt used must be free from chlorine and iron; and the solution should give no reaction when tested, as in the case of a water with carbazol.

(6) The standard solution of sulphate of silver is required for the removal of chlorine from the water to be examined. It is prepared by dissolving 4·3943 grammes of the salt in pure distilled water and making up to one litre. The sul-

phate is preferably obtained by dissolving metallic silver in pure sulphuric acid. The solution should be tested with carbazol in the same way as will be presently described for water; if perfectly pure no reaction will be obtained. As sulphate of silver is often prepared by precipitation from the nitrate, it is very apt to contain nitric acid, and consequently if the source of the salt be not known, this test should on no account be omitted.

Having described the preparation of the reagents, the method of making the determinations may now be considered more in detail. Assuming the water to be free from all substances capable of affecting the accuracy of the results, the process is carried out as follows: Two cubic centimetres of the water is carefully delivered by means of a 2 cc. pipette into the bottom of a test tube; 4 cc. of sulphuric acid is added, and the solution thoroughly mixed by the help of a glass rod. The test tube is then immersed in cold water, and when well-cooled 1 cc. of the sulphuric acid solution of carbazol is added, and the whole again mixed as before. The intensity of the color is now observed, and a little experience enables a fairly good opinion to be formed of the quantity of nitric acid present. Suppose that the water is roughly estimated to contain about ·15 parts N per 100,000, solutions of potassic nitrate, containing ·11, ·15, ·19 parts N, are selected from the series. Two cubic centimetres are taken from each and treated side by side with a fresh quantity of the water, precisely as described for the preliminary experiment, the various operations being performed as nearly simultaneously as possible with each of the samples, and under precisely similar conditions. Two or three minutes after the carbazol has been added, the intensity of the color of each is observed. If that given by the water is matched by any of the standard solutions, the estimation is at an end. Similarly, if it falls between two of these, the mean may be taken as representing the N present in cases in which great accuracy is not required. If this be done, the maximum error will be ·02 N or ·09 parts HNO_3 per 100,000. If greater exactness be required, or it be found that the color given by the water is either darker or lighter than that given by all

the standard solutions, a new trial must be made. In such a case the water must be again tested simultaneously with the solutions with which it is to be compared. This is rendered principally necessary for the reason that the shade of the solutions to which the carbazol has been added is apt to change on standing. Hence, it is desirable that the water, and the standard potassic nitrate with which it is to be compared, should have the carbazol added at as nearly the same time as possible. When finally the color falls between that given by any two consecutive members of the standard potassic nitrate series, the estimation may be considered at an end, and the mean of these solutions taken as representing the N present. The maximum error in this case will be only ·01 N per 100,000 parts, and the mean error slightly more than ·005. This degree of accuracy is believed by the author to be quite sufficient for, if indeed it does not exceed the needs of, all ordinary cases of water analysis for sanitary purposes, for which the process was specially devised. If occasionally, however, greater accuracy is desirable, the determinations recorded in the early portion of this paper show that the average error can be reduced to ·0036 parts N per 100,000. In this case the standard solutions employed must differ from each other by ·01 parts N only. The additional accuracy gained, however, will scarcely repay for the extra time and labor required, and even in this case, as will be seen by a reference to the above determinations, the error may amount to ·01 parts N per 100,000.

In the course of a great many experiments I have observed, even when the utmost care has been taken, that two solutions, nominally containing the same amount of nitric acid, occasionally give a very slight though distinctly perceptible difference in shade when tested side by side. Whatever may be their cause, such differences are extremely slight, and if proper care be taken do not materially affect the value of the process.

I cannot too strongly insist upon the necessity of scrupulous cleanliness at all stages of the analysis. The quantity of water operated upon is so small, that if the greatest care be not exercised throughout, sources of con-

siderable error may be readily introduced. The test tubes used in the process may be conveniently 5 x $\frac{5}{8}$ inches in size. It is scarcely necessary to add that they should always be dry when used, and rinsed out carefully with distilled water when put aside.

In comparing the color given by a water with that produced by standard potassic nitrate, it is necessary only to examine the solutions *through* the tubes; differences in shade, which can only be detected by looking through the length of the columns of liquid, may be disregarded. It is well to use the same 2 cc. pipette for measuring both the water and the standard potassic nitrate; the effect of any error in graduation is thus neutralized.

I have made experiments to ascertain whether the intensity of color produced is strictly proportional to the nitric acid present, with a view to render the use of a colorimeter possible and thus to avoid the time and trouble necessary to match the colors given by the waters. The result of these experiments, which were made with a Duboscq instrument, show conclusively that the changes already referred to in both tint and intensity after the addition of the carbazol, occur more rapidly with the light than with the dark solutions, and hence they are not strictly comparable.

INFLUENCE OF NITRITES.

It has been already pointed out that nitrous acid behaves similarly to nitric acid in its action on a sulphuric acid solution of carbazol. In order to estimate to what extent its influence would be felt when present in the water to be examined for nitrates, several solutions of silver nitrite were carefully prepared and estimated precisely as if they contained a nitrate.

The results obtained are given in the following table:

RESULTS EXPRESSED AS N IN 100,000 PARTS.

Present as $AgNO_2$.	*Found.*	*Error.*	*Corrected by deducting one-fifth from amount found.*
·10	·12	·02	·096
·20	·25	·05	·200
·30	·37	·07	·296

It will be observed that the error may be very nearly corrected by deducting one-fifth from the amount found. In the presence of nitrates, this correction, of course, will only be possible in cases in which the quantity of the nitrous acid present has been previously ascertained. A correction, however, would be rarely necessary.

INFLUENCE OF IRON.

Although a solution of ferrous sulphate gives no reaction with carbazol, nitrates are apt to be overestimated in the presence of iron in the ferrous condition. Ferric salts, however, acting like other oxidizing agents, are themselves able to give the characteristic green color with carbazol. I have made a number of experiments with solutions of potassic nitrate in the presence of both Fe'' and Fe''' in varying amounts, and have ascertained that if iron be not present in quantities greater than 0·1 parts per 100,000, the error will not exceed ·01 parts in 100,000. The condition of a water with regard to iron may be ascertained sufficiently accurately in a few seconds by the help of ammonic sulphide. As this is a test which should always be made in the examination of water for sanitary purposes, no extra trouble is involved. In a case in which iron is present in large quantities, it can be easily eliminated by rendering the water slightly alkaline, evaporating to dryness, and redissolving the soluble residue in the same volume of pure distilled water, as was taken of the water under examination.

INFLUENCE OF CHLORIDES.

Chlorides form by far the most serious source of error in this process by intensifying the action of the nitric acid. If, however, nitrates be absent, chlorides give no reaction with carbazol. Were it not for the fact that the chlorine can be perfectly removed in the space of a very few minutes, the general usefulness of the method would be much restricted. In order to remove the chlorine I use the standard sulphate of silver already referred to, 1 cc. of which, when consumed by 100 cc. of water, is equivalent to one part of Cl in 100,000 parts of water. Having first determined the chlorine present, by means of a standard nitrate

of silver solution of equivalent strength, the exact quantity of sulphate of silver required is known. I proceed as follows: A flask, graduated on the neck at 100 cc. and 110 cc., is filled up to the 100 cc. mark with the water to be examined. The necessary quantity of sulphate of silver is next added and then 2 cc. of the solution of aluminic sulphate previously described; finally, the contents of the flask are brought up to the 110 cc. mark by the addition of pure distilled water. The whole is shaken up and filtered; the first portion of the filtrate, which will contain any foreign substances derived from the filter paper, is thrown away. The aluminic sulphate, by reacting with the carbonates usually present in the water, and thus giving rise to the precipitation of alumina, facilitates the removal of the precipitated chloride of silver, which otherwise, under the conditions given above, is extremely difficult to separate and may even still pass through the paper after refiltering many times. When the filtrate is perfectly bright, a portion is tested to make sure that all the chlorine is removed; the estimation is then made precisely as already described, the amount found being increased by one-tenth to compensate for the dilution of the 100 cc. of the water taken to 110 cc.

It is obvious that such a flask, as I have described, cannot be used in cases in which the Cl exceeds eight parts per 100,000, unless the sulphate of silver solution be of greater strength than that which I have recommended. Similar methods will, however, readily suggest themselves.

In a preliminary paper* published on this process, I mentioned that probably diphenylamine, and other compounds giving similar color reactions in the presence of concentrated sulphuric acid, might be used instead of carbazol for the *quantitative* estimation of nitrates in water. Shortly after this paper appeared, L. Spiegel† called attention to a process worked up by him, in which diphenylamine was actually used for this purpose. This is briefly described in

* *Ber.*, **21**, 3,302; this JOURNAL, **127**, 61.

† *Ber.*, **21**, 3,568.

the *Zeitschrift für Hygiene*, 1887, **2**, 189, and was quite unknown to me. Although differing in detail from that which I have devised, the principle is the same, diphenylamine taking the place of carbazol. Although Spiegel does not mention any experiments made to ascertain the influence of chlorides, it is probable that this will be found as considerable as I have found it in the case of carbazol.

THE ELECTROLYTIC METHOD APPLIED TO MERCURY.—SEPARATION FROM COPPER.

BY EDGAR F. SMITH AND LEE K. FRANKEL.

[*Read at the Stated Meeting of the Chemical Section, April 16, 1889.*]

The electrolytic precipitation of mercury has been successfully performed by different chemists; thus, J. B. Hannay (*Berichte d. d. chem. Gesellschaft*, **6**, 270) recommends a solution of mercury sulphate for this purpose, but gives no quantitative results. F. W. Clarke (*Am. Journal of Science*, **16**, 200; *Zeitschrift für analyt. Chemie*, **18**, 103) separated mercury from the solution of its chloride, freely acidulated with sulphuric acid, by using a current obtained from six Bunsen chromic acid cells. Classen and Ludwig (*Berichte d. d. chem. Gesellschaft*, **19**, 323) employed a mercury solution, rendered slightly acid with nitric acid, and a current affording ·5 – 1·0 cc. OH gas per minute. The time occupied in the deposition, at ordinary temperatures, was twelve to sixteen hours. Hoskinson (*Am. Chem. Journal*, **8**, 209) obtained good results with the nitrate. Smith and Knerr (*Am. Chem. Journal*, **8**, 209) employed a nitrate solution, in which there was considerable acid in excess, and with a current yielding 4 cc. OH gas per minute deposited ·1 gramme of mercury in forty-five minutes. In all of these methods, which permit of the separation of mercury from many other metals, the mercury is thrown out as a mirror-like deposit, and drops of metal are plainly discernible.

We have observed that this metal can be separated without difficulty from solutions containing a large excess of alkaline cyanide, and with a comparatively weak current. The solution used was the chloride. The conditions, time, strength of current and results are as follows, with mercury alone:

Solution Contained Hg.	Found Hg.	Per cent. Difference.	Quantity of KCN.	Total Dilution.	Time in Hours.	Current in cc. OH Gas per Minute.
Grammes.			*Grammes.*	*cc.*		*cc.*
·1945	·1953	+ ·41	·26	175	16	·2
. . .	·1948	+ ·14	·26	. . .	16	·2
. . .	·1946	+ ·05	1·30	. . .	24	. . .
. .	·1930	— ·77	1·30	. . .	24	. . .
. . .	·1945	. . .	1·30	. . .	12	·2
. . .	·1945	. . .	1·30	. . .	12	. . .
. . .	·1945	. . .	2·60	. . .	12	·2
. . .	·1944	— ·05	·65	. . .	12	. . .
. . .	·1942	— ·14	·65	. . .	12	·2
. . .	·1956	+ ·56	·65	. . .	12	·2
. . .	·1957	+ ·61	1·30	. . .	12	. . .
. . .	·1948	+ ·14	1·30	. . .	12	·2

The deposits in these determinations were compact, rather gray in color, and showed in few cases the drop-like nature so characteristic of mercury.

For washing purposes it was found best to use water only, because when this was followed with alcohol, we noticed that the latter detached thin films of metal, causing loss in consequence. The heat of the hand is sufficient to dry the deposit, though a warm iron plate may be used. Some of the deposits were allowed to dry slowly over sulphuric acid. In our experience, with about a hundred mercury depositions, we observed but five in which there was a slight oxidation of the metal. This only occurred when a film of water remained in contact for some time with the deposited mercury.

In working with copper solutions, under conditions similar to those mentioned above, we discovered that this metal would not separate until the alkaline cyanide was completely decomposed. We, therefore, undertook a series of experiments with solutions containing both mercury and copper, hoping to effect their electrolytic separation. This seemed advisable, as the attempts in this direction had thus

far not been as successful as might be desired (See Luckow, *Zeitschrift für analyt. Chemie*, **8**, 24, and Classen, *Berichte d. d. chem. Gesellschaft*, **17**, 2,467; also *Zeitschrift für analyt. Chemie*, **24**, 247).

Our mercury solution contained the same quantity of metal as in the first experiments. Seventy per cent. of copper was added in each case. The quantity of cyanide varied from ·65 grammes to 3·9 grammes; total dilution was 200 cc., and the current strength varied from ·1 to ·4 cc. OH gas per minute. Time, six to eighteen hours. Ten experiments were performed, and notwithstanding the mercury was completely deposited, slight quantities of copper were likewise thrown out of solution.

Thirty additional experiments were made; in each the quantity of mercury was ·1945 grammes, while the copper varied from fourteen to seventy per cent. The quantity of alkaline cyanide varied from 3·9 to 8·5 grammes; total dilution remained 200 cc. The current averaged ·4 cc. to ·12 cc. OH gas per minute. Time, eighteen hours. The best results were these:

Hg Taken.	Hg Found.	Difference in Per Cent
Grammes.		*Per Cent.*
.1945	·1932	— ·66
. . . .	·1920	— 1 28
. . . .	·1927	— ·92
. . . .	·1936	— ·46
. . . .	·1930	— ·77
. . . .	·1936	— ·46
. . . .	·1954	+ ·46
. . . .	·1938	— ·36
. . . .	·1923	— 1·13
. . . .	·1921	— 1·23

These, as well as the results obtained in twenty experiments made later, seem to indicate that the presence of the copper exercises considerable influence upon the precipitation of the mercury—retards it. This fact, we think, was confirmed by ten more experiments, in all of which a slight quantity of the mercury was retained in solution, notwithstanding the current was increased to 1·2 cc. OH gas per minute, and the amount of cyanide considerably reduced.

The time of each precipitation was continued through seventeen hours.

Our attention was next directed to ascertaining whether or not a stronger current might be used to throw out the mercury, and at the same time leave the copper in solution. The results with mercury alone were

Hg Present.	Hg Found.	Difference in Per Cent.	KCN in Grammes.	Total Dilution.	Current in cc. OH Gas per Minute.	Time in Hours.
			Grammes.	*cc.*	*cc.*	
·1833	·1827	— ·27	1·5	200	2·8	16
	·1832	— ·05	1·5	200	2·8	16
	·1834	+ ·05	1·5	200	2·8	16

Using the same quantity of mercury and varying amounts of copper the results were as follows:

Hg Present.	Per Cent. of Cu Present.	Hg Found.	Difference in Per Cent.	KCN in Grammes.	Total Dilution.	Current in cc. OH Gas.	Time in Hours.
	Per Cent.		*Per Cent.*	*Grammes.*	*cc.*		*Hours.*
·1833	1	·1821	— ·65	1·5	200	3·2 cc. to 4 cc. OH per minute.	16
. . .	10	·1828	— ·27	. . .	. . .		. . .
. . .	1	·1821	— ·65	. . .	. . .		. . .
. . .	14	·1833	. . .	. . .	. . .		. . .
. . .	10	·1821	— ·65	. . .	. . .		. . .
. . .	5	·1819	— ·76	. . .	. . .		. . .
. . .	3	·1815	— ·98	. . .	. . .		. . .
. . .	5	·1834	+ ·05	. . .	. . .		. . .
. . .	3	·1836	+ ·16	. . .	. . .		. . .

which are recorded in the order obtained, and while the differences in percentage from that required vary from +·05 per cent. to —·98 per cent., and in six cases out of nine show a deficiency in the mercury, yet a careful qualitative examination of each filtrate failed to detect this metal; the error must therefore be ascribed to other causes. It may not be improper to add that these determinations and separations were not always conducted in the same platinum vessels, and, further, those used by us ranged in weight from sixty-one to 135 grammes.

Where the quantity of copper exceeded twenty per cent. of the mercury, the results were unsatisfactory.

It is well known that silver can be separated quantitatively from its cyanide solution, but whether its separation from copper could be effected in the same manner as that by which mercury and copper were separated, was undetermined; to ascertain this, we made forty experiments: ten of which resulted as follows:

Ag Present.	Copper.	Ag Found.	Difference in Per Cent.	KCN in Grammes.	Current in OH Gas.	Time in Hours.	Dilution.	
	Per Cent.		*Per Cent.*	*Grammes*	*cc.*			
	10	·1257	+ 2·78		1		200	
	10	·1299	+ 6·20		1		200	
	10	·1225	+ ·16		1		200	
·1223	10	·1263	+ 3·20	·5 to 1·0	1	5 to 20	200	Copper precipitated with silver.
	10	·1257	+ 2·78		1		200	
	10	·1244	+ 1·71		1		200	
	10	·1251	+ 2·20		1		200	
	10	·1242	+ 1·55		1		200	

Later, we diminished the quantity of copper with no better result. On increasing the quantity of cyanide, and also the strength of the current, the silver was very notably retarded in its deposition. After carefully repeating the work with no better outcome, we feel justified in saying that the cyanide method cannot be applied in the electrolytic separation of these two metals.

The current employed by us was obtained from storage batteries of the Julien form. Each cell contains nineteen plates, each of which is five and three-quarter inches square. In a long experience, with almost every form of battery, in electrolytic work, we have not had the same even, steady current for a series of hours as with the Julien form, and recommend it to all engaged in similar experiments. See further *Berichte d. d. chem. Gesellschaft*, **21**, 2,892.

UNIVERSITY OF PENNSYLVANIA,
PHILADELPHIA, April 13, 1889.

ON THE PRESENT CONDITION OF THE PHILADELPHIA WATER SUPPLY. SECOND MONTHLY REPORT.

By SAMUEL C. HOOKER, Ph.D.

[*Read at the Stated Meeting of the Chemical Section, May 21, 1889.*]

In presenting my second report, it is with considerable pleasure that I am able to refer to a matter of very general interest and importance in connection with the water supply of this city. The northwestern portion of the city, which for years has had to endure all the inconveniences attendant upon almost continuously muddy water, will, sometime during the present month, be placed upon an equal footing with the other and heretofore more fortunate sections of the city, and will then be supplied from the East Park reservoir, instead of directly from the Schuylkill. The inhabitants of Philadelphia generally, and more particularly those of the district referred to, may be heartily congratulated on this change, which is unquestionably one of the most important improvements recently made in connection with city affairs. It may be of interest at the present time to recall some facts connected with the supply of this district.

Owing to the considerable elevation of this portion of Philadelphia, there has been no available reservoir high enough to supply it, and consequently water was pumped directly into the mains from the Schuylkill River, a process which had to be kept up continuously, regardless of what might be the condition of the river or how much it might be charged with storm water. The consequence of this is very obvious. At all times the water is more muddy, and frequently unquestionably far less wholesome than that which is supplied to other portions of the city, whose reservoir capacity is sufficiently large to allow of a plentiful supply without the necessity of drawing from the river when in its most unfavorable condition. In order to overcome these difficul-

ties land was purchased some years ago at Cambria and Thirtieth Streets, and a proposed Cambria reservoir was long talked about, but the project of construction presented so many difficulties, and promised to require a so much greater outlay of capital, per unit of storage capacity, than had been necessary in the construction of the other reservoirs, that the plan was eventually abandoned in favor of that to be put in operation in a few days.

As the height of the East Park reservoir is not sufficiently great to enable it to feed this district by gravity, arrangements have been made to pump the water into the mains after it has properly settled.

My first report has been somewhat criticised, and a number of suggestions have been made with regard to the plan of the work I have undertaken. The desirability has been urged, not only of increasing the determinations made, but also of the samples examined. It has been suggested that districts should be sought out, in which, owing to the neighborhood of the dead end of a main or to some other cause, the water is continually inferior to the average supply. The importance of these suggestions is self-evident, and it is much to be regretted that the great amount of time and labor required for carrying them out is entirely out of all proportion to that which I am able to devote to the subject. The *first* object of this investigation is to ascertain the true general condition of the water, as a whole, and when this has been done, it will be time enough to consider local causes of deterioration. With regard to the collection of the samples, I have taken no pains to select points at which, for purely local reasons, the water is likely to be exceptionally bad; neither have I endeavored to get as far away from the dead end of a main as possible, so that the water might be at its best. The samples which I am receiving are, I have every reason to believe, thoroughly representative of the water supplied to the districts in which they are drawn, and, taken as a whole, they unquestionably represent fairly the supply of the city.

With regard to increasing the number of the constituents

determined, I do not think that much would be gained at present by so doing, but as the investigation proceeds it may be found desirable to complete the chain of evidence either for or against the water, and no measures will be left untried which promise any reasonable degree of success in eliciting useful information.

It is much to be regretted that during the past month it has been found necessary to continue pumping from the Delaware at the Kensington station. The water drawn at this point, even when mixed with a large proportion from the Schuylkill, remains very decidedly inferior to the general supply of the city. In a very short time this station is to fall into disuse and no effort should be spared to avoid the necessity of having ever again to resort to it for city supply. Proper provision should be made at once to enable the Water Department, even in the case of emergency, to meet the city's requirements without having to draw a single gallon of water from this unquestionably much polluted point of the Delaware. The best thing that could be done in the public interest would be to dismantle this station in such a way that pumping here in the future would be an absolute impossibility.

Having reference to a statement made in my last report, my attention has been called by the Health Department to the fact that analyses of the water supply have been made regularly for its information during a number of years past. These analyses are withheld from the public, however, because it is feared that improper use might be made of them by individuals, and that figures might be sifted and distorted for the purpose of furthering private ends. If there is no better reasons for withholding these analyses than those which I have mentioned, it is to be hoped that, in future, matters will be regarded in a different light by the Department and that the public will be furnished with the information which rightly belongs to it. It would seem to me far more desirable that the public should be periodically told precisely to what extent the water is good or bad, how it is affected by circumstances attending its distribution, and what probable connection there is at different

times between the condition of the water supply and that of the public health. All figures, moreover, should be furnished to enable those who care to study the matter to do so.

During the period covered by this report, April 19th to May 17th, I have examined twenty-six samples of water and, taken as a whole, I am able to report very favorably on its condition. The water was, however, in a few instances extremely muddy.

The nitrates, which, during a part of the period covered by my first report, were somewhat high, have decreased considerably in quantity; the albuminoid ammonia, representing the nitrogenous organic matter in solution, is lower than that during the previous month and does not vary to any considerable extent in any of the samples examined.

I should have mentioned in my last report, that before determining the albuminoid and free ammonia, the water is carefully filtered through a good quality of paper, so as to remove as well as possible all solid particles, the presence of which would otherwise render it impossible to arrive at any correct idea of the true quality of the water, and would further make any comparison between the water supplied to the various sections of the city worse than useless. In certain cases, a filtration of this character is not able to remove some of the very fine mud held in suspension; this tells unfavorably on the analysis and is one reason, I believe, why, during the period covered by my first report, the Germantown water appeared to less advantage than that in other portions of the city.

My analyses so far show, when considered as a whole, that the actual quality (and here I have no reference to muddiness) of the Germantown water is not inferior to that of the general supply; on the contrary, I believe that if the storage capacity of the reservoir through which it passes, were sufficiently increased to allow the mud to subside properly and to avoid the necessity of drawing water at unfavorable times, it would be distinctly superior to much Schuylkill water that is supplied to other portions of the city.

The almost constantly muddy condition of the German-

town water is, however, most truly deplorable, and the attention of the authorities cannot be too earnestly called to it. The Water Department has certainly no more important task before it than the furnishing of this district with clean water

A diagram is appended, as in my last report, and as several comments have been made in regard to the former one, I would take this opportunity of mentioning that *all* the curves are not constructed to represent parts per 100,000, because if this were attempted, either the size of the diagram would have to be enormously increased, or several diagrams would be necessary.

ANALYSES OF THE PHILADELPHIA WATER SUPPLY.

RESULTS EXPRESSED IN PARTS PER 100,000.

Kensington, Beach and Vienna.

Date. 1889.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Nitrogen of Nitrates.
April 19th, ...	·40	·0000	·0090	·08
" 26th, ...	·36	·0045	·0115	·05
May 3d, ...	·29	·0000	·0110	. . .
" 10th, ...	·37	·0030	·0080	. . .
" 17th, ...	·26	·0010	·0050	·11
Average, ...	·33	·0017	·0089	·08

West Philadelphia.

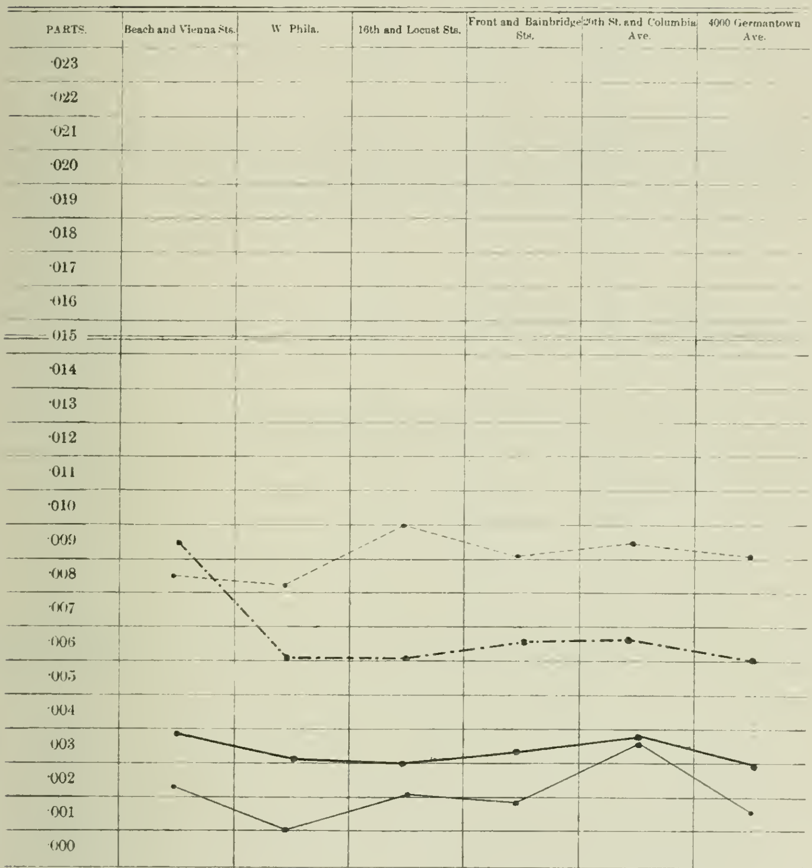
April 19th, Not analyzed.				
" 26th, ...	·30	·0015	·0055	·077
May 3d, ...	·24	·0000	·0060	. . .
" 10th, ...	·25	·0005	·0050	. . .
" 17th, ...	·26	·0000	·0060	·077
Average, ...	·26	·0005	0056	·077

Sixteenth and Locust.

April 19th, Not analyzed.				
" 26th, ...	·32	·0020	·0060	·088
May 3d, ...	·19	·0010	·0060	. . .
" 10th, ...	·26	·0020	·0050	·099
" 17th, ...	·26	. . .	. . .	·099
Average, ...	·25	·0016	·0056	·095

DIAGRAM SHOWING THE AVERAGE RELATIVE CONDITION OF THE WATER SUPPLY AT DIFFERENT POINTS OF THE CITY. April 19 to May 17, 1889.

(CONSTRUCTED FROM 26 ANALYSES



EXPLANATORY NOTES:

Nitrogen of Nitrates in parts per 10,000.
Representing, when in excess, animal matter, which by natural processes of purification has been rendered harmless.

Albuminoid Ammonia in parts per 100,000.
Representing, when in excess, nitrogenous organic matter of the most dangerous type.

Chlorine in parts per 1,000.
Representing, when in excess, present or past sewage contamination.

Free Ammonia in parts per 100,000.
Representing, when in excess, decaying organic matter.

Provided that the two lower curves do not vary much in height from those given, the condition of the water may be regarded as satisfactory so long as the two upper curves remain below the double line through ·015.

It will be understood that the smaller the quantity of the substances indicated by the above curves, the more satisfactory the condition of the water. In other words, the water is most satisfactory with regard to each particular substance, at the lowest point of each curve.

Front and Bainbridge.

Date. 1889.		*Chlorine.*	*Free Ammonia.*	*Albuminoid Ammonia.*	*Nitrogen of Nitrates.*
April 19th,	Not analyzed.				
" 26th,	. . . . .	·33	·0005	·0060	·077
May 3d,	. . . . .	·22	·0010	·0075	. . .
" 10th,	. . . . .	·27	·0010	·0055	. . .
" 17th,	. . . . .	·29	·0025	·0060	·088
Average,	. . . . .	.27	·0012	·0062	·082

Twentieth and Columbia Avenue.

April 19th,	Not analyzed.				
" 26th,	. . . . .	·33	·0025	·0070	·066
May 3d,	. . . . .	·26	·0020	·0055	. . .
" 10th,	. . . . .	·31	·0030	·0060	·099
" 17th,	. . . . .	·30	·0020	·0060	·088
Average,	. . . . .	·30	·0027	·0061	·084

4000 Germantown Avenue.

April 19th,	. . . . .	·26	·0025	·0055	·08
" 26th,	. . . . .	·28	·0015	·0065	·088
May 3d,	. . . . .	·21	·0000	·0060	. . .
" 10th,	. . . . .	·24	·0010	·0040	. . .
" 17th,	. . . . .	·25	·0005	·0055	·088
Average,	. . . . .	·24	·0011	·0055	·082

4416 Chestnut Street.

On the OCCURRENCE of PARAFFINE in CRUDE PETROLEUM.

[*An Abstract of a Thesis by E. A. Partridge, Class of '89, Univ. of Pa. Read before the Chemical Section by Prof. S. P. Sadtler.*]

It is well known that the paraffine obtained by the distillation of petroleum residues is crystalline, while that obtained directly (as in the filtration of residuum) is amorphous. Ozokerite or ceresine differs but slightly from paraffine, the principal distinction being want of crystalline structure in it as found. Other characteristics, such as the melting point, specific gravity, etc., vary in both, and so are not of importance in a comparison. Hence it has been asked, is the paraffine occurring in petroleum and ozokerite identical with that which is produced by their distillation?

As crystalline paraffine could be obtained from ozokerite by distillation alone, many persons have supposed that it was engendered in the process. Recently, however, crystalline paraffine has been obtained from ozokerite by dissolving the latter in warm amyl alcohol; on cooling the greater part separates out in crystals having the lustre of mother-of-pearl. By repetition of this process, a substance is obtained that is scarcely to be distinguished from the paraffine obtained by distillation. Apparently there exists then in ozokerite, together with paraffine, other substances not capable of crystallization which keep the paraffine from crystallizing. These colloids appear to be separated by amyl alcohol in virtue of their greater solubility in that menstruum. It is also reasonable to suppose that they undergo change or decomposition by distillation.

So as petroleum residues are amorphous, and the crystalline paraffine is first produced by distillation, it has been argued that the paraffine present in crude petroleum is approximately the same thing as ozokerite.

This, however, is not sufficient to establish the pyrogenic origin of all crystallized paraffine, as crystals can be obtained from the amorphous residues by distillation at normal or reduced pressure or in a current of steam. To explain these facts two assumptions are possible. Either the chemical and physical properties of all or some of the solid constituents are changed by the distillation, and the paraffine is changed from the amorphous into the crystalline variety, or the change produced by the distillation takes place in the medium (*i. e.*, the mother liquid) in which the paraffine exists. The change effected in ozokerite and in petroleum residues when crystalline paraffine is obtained by distillation, is to be regarded as a purification, and can be effected partially by treatment with amyl alcohol. In the same way, by repeated treatment of petroleum residuum with amyl alcohol, a substance of melting point 59° C. can be obtained, which cannot be distinguished from ordinary paraffine.

The treatment with amyl alcohol has therefore accomplished the same results as was obtained by distillation, and

the action is probably the same, *i. e.*, a partial separation of colloid substance. These facts point to the conclusion that crystallizable paraffine exists ready formed in both petroleum and in ozokerite, but in both cases other colloidal substances prevent its cystallization. By distillation, these colloids appear to be destroyed or changed so as to allow the paraffine to crystallize.

It is a generally known fact that liquids always appear among the products of the distillation of paraffine, no matter in what way the distillation be conducted. This shows that some paraffine is decomposed in the operation.

The name *proto-paraffine* has been given to ozokerite, and to the paraffine of petroleum in contra-distinction to *pyro-paraffine*, the name that has been applied to the paraffine obtained by distillation from any source.

According to Reichenbach, paraffine may crystallize in three forms: needles, angular grains and leaflets having the lustre of mother-of-pearl. Hofstädter, in an article on the identity of paraffine from different sources, confirmed this statement, and added farther that at first needles, then the angular forms, and then the leaflets are formed. Fritsche found, by means of the microscope, in the ethereal solution of ozokerite, very fine and thin crystal-leaflets concentrically grouped, and in the alcoholic solution fine irregular leaflets. Zaloziecki has recently developed these microscopic investigations to a much greater extent. According to this observer, the principal part of paraffine, as seen under the microscope, consists of shining stratified leaflets with a darker edge. The most characteristic and well-developed crystals are formed by dissolving paraffine in a mixture of ethyl and amyl alcohols and chilling. The crystals are rhombic or hexagonal tablets or leaves, and are quite regularly formed. They are unequally developed in different varieties of paraffine. The best developed are those obtained from ceresine. Their relative size and appearance give an indication as to the purity of the paraffine, and, as they are always present, they are to be counted among the characteristic tests for paraffine. Reichenbach observed that mere traces of empyreumatic oil prevented their formation.

The old method of determining the amount of paraffine in petroleum was to carry out the refining process on a small scale; that is, to distil the residue from the kerosene oils to coking, chill out the paraffine, press it thoroughly between filter-paper and weigh the residue. The sources of error in this procedure are manifold; the principal one is the solubility of paraffine in oils, which depends upon the character of both the paraffine and the oil, and also upon the temperature. The next greatest source of error is variation in the process of distillation and the difference between working on the small scale and on the large scale.

In most cases, where a paraffine determination is to be carried out, one has to deal with a mixture of paraffine with liquid oils. Now, paraffine is not a substance defined by characteristic physical properties which distinguish it from the liquid portions of petroleum. It consists of a mixture of homologous hydrocarbons, which form a solid under ordinary conditions. The hydrocarbons of this mixture show a gradation in their properties, and gradually approximate to those which are liquid at ordinary temperatures. It is a well-known fact that a separation of these homologues is entirely impossible by distillation. It has also been ascertained that the liquid constituents of petroleum do not always possess boiling points that are lower than those of the solid constituents. This shows that we have to deal not merely with hydrocarbons of one but of several series.

When determinations of the amount of paraffine are to be made, then it becomes necessary to specify with exactness what is to be called paraffine. The most definite property that can be made use of for this purpose is the melting point. For several reasons it is convenient to include under this name hydrocarbons of melting point as low as 35°–40° C.

The method proposed by Zaloziecki for the determination of paraffine is the following: The most volatile portions of the petroleum are separated by distillation, until the thermometer shows 200° C. These portions are separated, as they exert great solvent action upon paraffine. At the same time he finds that no pyro-paraffine is formed under this temperature. A weighed portion of the residue

is taken and mixed with ten parts by weight of amyl alcohol and ten parts of seventy-five per cent. ethyl alcohol: the mixture is then chilled for twelve hours to 0° C. It is then filtered cold, washed first with a mixture of amyl and ethyl alcohols, and then with ethyl alcohol alone. The paraffine is transferred to a small porcelain evaporating dish and dried at 110° C. It is then heated with concentrated sulphuric acid to 150°–160° C. for fifteen to thirty minutes with constant stirring. The acid is then neutralized and the paraffine extracted by petroleum ether. On evaporation of the solvent, the paraffine is dried at 100° C. and weighed. Zaloziecki found, according to this method, in three samples of Galician petroleums, 4·6, 5·8 and 6·5 per cent., respectively, of proto-paraffine. The method was carried out as above, with four samples of American petroleums, Colorado oil from Florence, Col.; Warren County oil from Wing Well, Warren, Pa.; Washington oil from Washington County, Pa.; Middle District oil from Butler County, Pa., all furnished by Professor Sadtler.

They were very different in physical properties and in appearance, the Colorado oil being a much heavier oil than the others and the Washington oil being an amber oil, while the other two were of the ordinary dark green color and consistence. The losses on distillation to 200° C. were very different, being about one-tenth in the case of the Colorado oil and nearly one-half in the case of the others. The percentages of partially refined proto-paraffine in the four reduced oils (all below 200° C. off) were as follows: for the Colorado oil, 23·9 per cent.; for the Warren oil, 26·5 per cent.; for the Washington oil, 26·6 per cent.; and for the Middle District oil, 28·2 per cent.

The question now arises, what value has this determination of the proto-paraffine which may exist in an oil. As before said, a portion of the paraffine is always decomposed in distillation at temperatures sufficiently high to drive over the paraffine oils, so the yield of pyro-paraffine is always less than the proto-paraffine shown to be present originally. Zaloziecki found this in the case of the several Galician oils he examined. Corresponding to the 4·6, 5·8 and 6·5 per cent.

of proto-paraffine in the several oils, he obtained 2·18, 2·65 and 2·35 per cent., respectively, of pyro-paraffine.

For the present, however, the extraction of proto-paraffine on a large scale by means of such solvents as amyl and ethyl alcohols is out of the question on account of their cost. A distillation, under reduced pressure and with superheated steam, would, however, prevent much of the decomposition of the original proto-paraffine and increase the yield of pyro-paraffine.

This study of Zaloziecki's method and the examination of American oils was suggested by Professor Sadtler and carried out in his laboratory.

GIFTS TO THE LIBRARY OF THE FRANKLIN INSTITUTE.

Agricultural Experiment Station of the Agricultural and Mechanical College, Auburn, Ala. Bulletin No. 5. New Series. From the Station.

Albany Medical College. Historical Address by David Murray. From Willis G. Tucker, M. D.

American Institute of Mining Engineers:

- Rothwell. The Present Status of Electric Transmission of Power.
- Cook. Tuyere Slagging-Valve.
- Hofman. Gold-Milling in the Black Hills.
- Glenn. Notes on the Electrolytic Assay of Copper.
- Blake. Note upon some Results of the Storage of Water in Arizona.
- Blake. The Copper Deposits of Copper Basin, Arizona, and their Origin.
- Bowden. Biographical Notice of Eric C. Schaufuss.
- Cook. The Wenström Magnetic Separator.
- Potter. Note on the Use of Crude Petroleum as Fuel for Raising Steam at the South Chicago Works.
- Carpenter. Ore-Deposits of the Black Hills of Dakota.
- Proceedings of the Fifty-third (Nineteenth Annual) Meeting, New York City, February, 1889.
- Smith. Nails from Tin Scrap.
- Hunt. Steel Rails. Discussion.
- Potter. Some Thoughts Relating to the American Institute of Mining Engineers and its Mission.
- Munroe. An Automatic Dumping Cradle for Mine Cars.
- Williams. The Determination of Silicon in Ferro-Silicons; its Occurrence in Aluminium as Graphitoidal Silicon; and a Study of its Reactions with Alkaline Carbonates.

American Institute of Mining Engineers:
Munroe. Automatic Dumping Cradle. Discussion.
Ashburner. The Geology of Buffalo as Related to Natural-Gas Explorations along the Niagara River.
From the Institute.
American Iron and Steel Association. Annual Statistical Report for 1888.
From the Secretary.
Arkansas Geological Survey. Annual Report for 1888. Vol. 1.
From the State Geologist.
Association Française pour l'Avancement des Sciences. Sixteenth and Seventeenth Session: 1887 and 1888. From the Association.
Baltimore Health Department. Annual Report for 1888.
From the Secretary of the Department.
Bibliotheques et des Archives. Annuaire 1889. Bulletin No. 2. 1888.
From the Minister of Public Instruction.
Board of Supervising Inspectors of Steam Vessels. Proceedings. Thirty-Seventh Annual Meeting. Part 1. From the Board.
Bureau of Statistics. Quarterly Report No. 2. 1888-89.
From the Chief of the Bureau.
Camden, N. J. Department Reports. 1888.
Reports of the Water Department for 1873, 1874, 1875, 1876, 1878, 1886, 1887 and 1888.
From the Chief Engineer, Water Department.
Canadian Society of Civil Engineers. Transactions. Vol. 2. Part 2.
From the Society.
Carnegie, Andrew. Industries of Pennsylvania.
From the American Iron and Steel Association.
Carnegie, Andrew. Pennsylvania's Industries and Railroad Policy.
From the Author.
Chicago. Historical Society Proceedings. Quarterly Meeting. April, 1889.
From the Society.
Cincinnati Corrugating Company. Catalogue. From the Company.
Clifford, H. E. H. Note on the Efficiency of Small Electro-Motors.
From the Author.
Connecticut Agricultural Experiment Station. Annual Report for 1889. Part 1. Bulletin No 97. From the Station.
Coutie, Wm. Atoms of Elements. Part 2. From the Author.
Davenport Academy of Natural Sciences. Proceedings. Vol. 5. Part 1.
From the Academy.
Dexter Manufacturing Company. Catalogue of Folding Machines.
From the Company.
Dickinson College. One Hundred and Sixth Annual Catalogue.
From Prof. Chas. F. Himes.
Electrical Periodicals; 363 odd numbers of the following journals:
Electrician. London.
Electrician. New York.
Electrical Engineer. London.

Electrical Periodicals:

Electrical Review. New York.
Electrical World. New York.
Telegraphic Journal. London.
Western Electrician. Chicago. From David Brooks.

Engineers' Society of Western Pennsylvania. Proceedings. March 19, 1889. From the Society.

English Pilot. Part 1 and 4th book. London, 1629 and 1638. From Dr. Isaac Norris.

Fall River, Mass. Eleventh Annual Report of the Board of Health for 1888. From the Board.

Financial and Mining Record. Vols. 19 to 22. 1886 and 1887. From Percy A. Bivins.

Franklin Reformatory Home. Seventeenth Annual Report. From the Home.

Grand Trunk Railway of Canada. Semi-Annual Report, December 31, 1888. From Mr. Hickson.

Hartford, Conn. Fourth Annual Report of the Board of Health for year ending February 28, 1889. From the Board.

Hartford, Conn. Thirty-fifth Annual Report of the Board of Water Commissioners for year ending March 1, 1889. From the Board.

Harvard College Observatory Annals. Vol. 18. Parts 7 and 8. Vol. 20. Part 1. From Prof. E. C. Pickering.

Henry Draper Memorial. Third Annual Report. From the same.

Hydrographic Office United States. Pilot Chart of the North Atlantic Ocean. May, 1889. From the Philadelphia Branch.

Imperial University, Tokyo. Journal of the College of Science. Vol. 2. Part 5. From the University.

Indiana. Geological Reconnaissance.
Geological Report, 1879–80. From John A. Oakes.

Iron and Steel Institute. London. Journal No. 2. 1888. From the Institute.

Manchester Steam Users' Association, Boiler Explosions. Board of Trade Reports. 1879–82. From the Association.

Massachusetts State Agricultural Experiment Station. Sixth Annual Report. Bulletin No. 38. From the Station.

Master Builders' Exchange. Hand-book. From the President.

Mechanical Tests of Building Material made for the Commissioners for the Erection of the Public Buildings, Phila. From Chas. E. Ronaldson.

Mercantile Library of Philadelphia. Bulletin No. 27. From the Library.

Meteorological Observations Recorded at Six Stations in India. October to December, 1888. From the Meteorological Department of India.

Michigan State Board of Health. Sixteenth Annual Report. From the Secretary.

Minnesota Geological and Natural History Survey. Sixteenth Annual Report. From the State Geologist.

National Association of Builders. Third Annual Convention.
From the Secretary.

New Bedford, Mass. Tenth Annual Report of the Board of Health.
From the Board.

New Bedford, Mass. Nineteenth Annual Report of the Water Board for 1888. From the Board.

New Jersey Agricultural Experiment Station. Bulletin No. 52 to 55 inclusive.
From Prof. G. H. Cook.

New Jersey Historical Society. Proceedings. Second Series. Vol. 10. No. 3. From the Society.

New Jersey State Lunatic Asylum. Annual Reports for 1848 to 1888 (1860 to 1870 in duplicate).
From the Hon. Caleb S. Green, Secretary of the Asylum.

New York City Aqueduct Commission. Report on Researches concerning High Masonry Dams. From the Commission.

New Zealand Meteorological Report for 1885.
From the Director of the Colonial Museum.

Norfolk and Western Railroad Company. Eighth Annual Report.
From the Company.

North Carolina Agricultural Experiment Station. Bulletin No. 62½.
From the Station.

Osborne, Richard B. Professional Biography of Moncure Robinson.
From the Author.

Patent Office, British. Abridgments relating to :
Acids, Alkalies, etc. Division 2 and 3.
Wearing Apparel. Division 1.
Name Index to November, 1888.
Subject Matter Index, November, 1888.
Specifications of Inventions. Vols. 42, 44 to 72, 74 and 75.

Patent Office, United States. Specifications and Drawings, March, 1889.
From the Office.

Pennsylvania State College. Catalogue. 1888–89. From the College.

Peters, C. H. F. Celestial Charts made at the Litchfield Observatory of Hamilton College. From the Author.

Philadelphia City Institute. Thirty-seventh Annual Report.
From the Managers.

Plutarch's Lives. Cassell's National Library. From Cassell & Co.

Practische Maschinen Constructeur, Erster und Zweiter Jahrgang. 1868 and 1869. From Hugo Bilgram.

Providence Public Library. Eleventh Annual Report.
From the Librarian.

Reading, Pa. Report of the Board of Health for 1888. From the Board.

Rose Polytechnic Institute. Seventh Annual Catalogue.
From the Institute.

Royal Statistical Society. General Index to Journal. From the Society.

Signal Office, U. S. A. Appendix 5 to the Annual Report of the Chief Signal Officer. 1888. From the Office.

Springer Torsion Balance Company. Prospectus. From the Company.

Taunton, Mass. Annual Report of the Board of Health. 1888.
From the Board.

Trade Catalogues. Branford Lock Works.
Churchill & Co.
Disston & Sons.
Ironmonger Diary. 4 vols.
Markley, Alling & Co.
Montgomery & Co.
Russell, Erwin & Co. 3 vols.
Sargent & Co.
Simmons Hardware Co.
Walter's Sons.
From A. C. Albrecht, Superintendent American Machine Co.

Treasury, U. S. Annual Report of the Secretary. 1888. Finance.
From the Secretary.

United States Commission of Fish and Fisheries. The Fishery Industry of the United States. Section 5. Vols. 1 and 2.
From the Commission.

U. S. Department of Agriculture:
Division of Chemistry. Bulletin No. 20.
Division of Entomology. Periodical. Bulletin No. 9.
Hog Cholera, its History, Nature and Treatment.
Quarterly Bulletin. March, 1889.
Report of the Statistician, No. 61. From the Department.

U. S. Department of State. Report from the Consuls, February, 1889.
From the Department.

United States Geological Survey. Seventh Annual Report, 1885–86.
From the Director.

United States Mint. Annual Report of the Director for 1888.
From the Director.

University Club of Philadelphia. Officers, Committees, Charter, By-Laws, etc.
From Henry Pemberton, Jr.

University of Wisconsin. Agricultural Experiment Station. Bulletin No 19.
From the Station.

Vereines Deutscher Ingenieure. Statut, 1867. Zeitschrift, Band 12 to 17. 1868 to 1873. From Hugo Bilgrim.

Waltham, Mass. City Documents for 1866, 1867, 1868, 1869, 1870, 1871, 1880, 1881, 1883, 1885, 1886, 1887.
The Taxable Valuation of the Real and Personal Estates, with the Amounts of Tax in Waltham, for the year 1885. From the City Clerk.

Wisconsin. Second and Third Biennial Reports of the State Board of Charities and Reform for 1885–86 and 1887–88. From the Board.

Wisconsin. State Historical Society. Proceedings Thirty-sixth Annual Meeting. From the Society.

ANNUAL REPORT

OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE, FOR THE SESSIONS 1888–1889.

The number of pupils attending the Drawing School has been less this year than last, but as other similar schools have had the same experience, it is evidently due to outside causes and does not indicate any loss of prestige. On the contrary, the system of instruction has been greatly improved, and the efficiency correspondingly increased. This is particularly the case with the Junior and Intermediate Classes in Mechanical Drawing, where all problems not directly useful have been eliminated, and the course so modelled as to be logical, concentrated, concise, and at the same time more comprehensive than ever before. Excellent opportunity is given the pupils to become thoroughly grounded in the principles, and any failure on the part of any of them to profit by it, is due either to natural incapacity or to want of appreciation of or lack of attention to, the theoretical studies which constitute a large portion of the work. If those desirous of learning Mechanical Drawing would only commence at the beginning and go understandingly through the entire course, they would become thoroughly interested in the subject and would, at the end, be in a position to make themselves immediately useful in a draughting office or industrial establishment, and would have mastered things which, as apprentices in such establishments, they would never get an opportunity to learn.

This is equally true of those desiring to take up Architectural Drawing. It is the ability to handle crooked, complicated and difficult problems that makes any individual architect, draughtsman or mechanic more valuable than his fellows, and although a natural gift of genius may occasionally supply the place of education and training to some extent, yet such gifts are rare, and even when they do occur, the education has to be obtained afterwards by overwork.

The Free Hand Classes have been favored this year with an unusual amount of natural talent and have consequently been very successful. Considering the total number of hours actually spent at the work, the quantity and quality of the result attained make a gratifying showing.

Much credit is due to the ability and earnestness of the instructors: Messrs. Clement Remington, Willis H. Groat, John F. Rowland and George W. Irons.

The following pupils are entitled to Honorable mention:

In the Senior Mechanical Class.

William H. Schalliol,	Howard W. White,	Thomas W. Lawrence,
A. S. Berquist,	Lucien E. Picolet,	John Morris Bush.

In the Intermediate Classes.

John S. Rooke,	Charles W. Godfrey,	Gustav Friedler,
George C. Tilton,	Clifford M. Talley,	Robert G. Hienerwald,
Alexander H. Watt,	Donald Frazer,	W. E. Wilkinson.

In the Junior Mechanical Classes.

Frank S. Thompson,	John G. Johnson,	J. Hüster,
John Simpson,	Henry J. Upp,	James L. Garnett,
	W. A. Leavitt, Jr.	

In the Architectural Class.

George W. Haldeman,	Paul A. Davis,
Charles B. Jarden,	Henry Kerr.

In the Free Hand Class.

Robert F. Schleicher,	Charles Nacke,	Arthur B. Davenport,
Oscar Wenderoth,		Kate F. Dinan.

In the Oil-Painting Class.

Charles A. Koch,	Mrs. L. Nace,	George Lethy.

The following pupils are awarded scholarships from the B. H. Bartol Fund, entitling them to tickets for the next term, beginning September 23, 1889:

Intermediate Mechanical Class.

John S. Rooke,	Donald Frazer.

Junior Mechanical Class.

Frank S. Thompson,	J. Hüster.

Architectural Class.

Paul A. Davis.

Free Hand Class.

Robert F. Schleicher.

The following pupils having attended a full course of four terms, with satisfactory results, are awarded certificates to that effect:

Louis Eichhorn,	James Exley,	George E. Drum,
William H. Schalliol,	Charles W. Leng,	William Grieser,
Howard W. White,	George Bardsley,	George W. Haldeman,
Lucien E. Picolet,	Henry H. Alcock,	Daniel McLaughlin,
Thomas W. Lawrence,	Emil Lukert,	William Bartholomew,
Morris T. Patterson,	George Fred. Becker,	William L. Bushnell,
William Halpin,	Charles Doellber,	Howard M. Craig,
John Morris Bush,	Kenneth J. Easby,	John Kenney,
William C. Gray,	George S. Neff,	George H. Robinson,
William C. Brockmeyer,	Leburton P. Gardner,	Frederick De Ginther,
William H. Lippert,		Howard L. Dunlop.

It is to be regretted that the class-rooms are not sufficient to accommodate the entire school on two evenings in the week, as was the original practice. Such an arrangement would increase the energy and enthusiasm and remove the tiresome effect of continuous night work from the instructors. The school sessions could then be fixed on different evenings from the lectures, and thus avoid the annoyance to the lecturer and audience, caused by the noise on the stairway, made by a few ill-bred and unruly pupils during the exit of the classes. I shall endeavor to plan a rearrangement of the rooms to accomplish this.

WILLIAM H. THORNE,
Director.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, May 15, 1889.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 15, 1889.

JOSEPH M. WILSON, President, in the Chair.

Present, 128 members and sixteen visitors.

Additions to membership since last report, 39.

Mr. S. LLOYD WIEGAND was elected as a trustee of the Elliot Cresson Fund, to fill the vacancy caused by the death of JOHN WIEGAND.

Mr. JAMES S. McCOY, of New York, gave a description of the Pneumatic Tool of the American Pneumatic Tool Company and exhibited the tool in operation surfacing and engraving stone, engraving upon wood, executing *repoussé* work, etc. Specimens of the products were exhibited.

The subject was referred for investigation to the Committee on Science and the Arts.

Mr. FRED. E. IVES made some remarks on the subject of portable optical lanterns, and exhibited vertical lantern, megascope, microscope, polariscope and spectrum projection attachments of novel construction, adapted to his portable folding lantern.

Mr. IVES' improvements were referred to the same committee for investigation and report.

Mr. S. LLOYD WIEGAND presented an abstract of the report of the Committee on Science and the Arts on "James Atkinson's Gas Engine," illustrating the subject by the use of a number of lantern slides.

The Secretary's report embraced some comments on the Paris Exhibition and the exhibition of a number of views of some of the most notable of the various buildings and structures.

Adjourned. WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR JANUARY, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, January 31, 1889.

TEMPERATURE.

The mean temperature for January, 1889, 31°·9, is about 5° above the average, and 9°·8 above that of January, 1888. The mean of the daily maximum temperature was 31°·6, and of the daily minimum temperature, 27°·2. The warmest period of the month was the 17th, and the coldest from the 19th to the 23d inclusive.

The highest temperatures reported were Westtown, 68°·0; Carlisle, 65°·0; Reading, 64°·5; McConnellsburg, 64°·0; Lancaster, 64°·0, and New Bloomfield, 64°·0. The lowest were Charlesville, minus 5°; Emporium, minus 3°; Honesdale, minus 3°; Smethport, minus 2°·5; Hollidaysburg, minus 2°; New Castle, minus 2°; Coudersport, minus 2°, and Wellsboro, minus 2°. Stations with the highest mean for the month were Philadelphia, 37°·3; Uniontown, 36°·5; Pittsburgh, 35°·2; Catawissa, 35°; Pottstown, 35°, and Indiana, 34°·9.

Those with the lowest were Eagles Mere, 26°·6; Honesdale, 27°·8; Phillipsburg, 28°·3; Greenville, 28°·7; Coudersport, 28°·6, and Clarion, 29°·1.

BAROMETER.

The mean pressure, 30·05, is ·05 below the normal. The highest readings noted were on the 17th, 19th and 23d, and the lowest on the 9th and 27th. That of the 9th accompanied the tornadoes which passed over the state on that date.

PRECIPITATION.

The average rainfall, including melted snow, was 3·54 inches, which is slightly above the normal. The fall was very evenly distributed, both during the month and over the state. Light snow squalls were frequent. The heaviest snowfall occurred on the 20th. The greatest totals in inches for the entire month were, Meadville, 21; Eagles Mere, 19; Coudersport, 18; Somerset, 13; Wellsboro, 12, and Rimersburg, 12. Very little snow remained on the ground at the end of the month.

WIND AND WEATHER.

The prevailing wind was from the west. On the 9th, several portions of the state were visited by tornadoes, which did a large amount of damage. Owing to the extreme mildness of the month much plowing was done and no ice was harvested. Winter grain is reported in good condition.

Average number.—Rainy days, 10; clear days, 9; cloudy days, 9.

MISCELLANEOUS PHENOMENA.

Snow.—Charlesville, 12th, 14th, 20th, 21st, 28th, 29th, 30th; Reading, 20th, 28th, 31st; Hollidaysburg, 7th, 11th, 14th, 20th, 21st, 27th, 28th, 31st; Wysox, 20th, 27th, 28th; Quakertown, 20th, 31st; Emporium, 20th, 24th; State College, 15th, 20th, 31st; Phillipsburg 6th, 7th, 9th, 11th, 20th, 21st, 28th, 29th, 30th, 31st; Coatesville, 20th; Clarion, 7th, 11th, 20th, 21st, 28th, 30th, 31st; Grampian Hills, 6th, 7th, 11th, 21st, 30th, 31st; Lock Haven, 21st, 23d; Catawissa, 20th, 28th, 31st; Meadville, 7th, 11th, 18th, 20th, 21st, 28th, 29th, 30th, 31st; Carlisle, 20th, 28th; Harrisburg, 20th, 21st; Swarthmore, 20th; Tionesta, 20th, 21st, 28th, 29th; McConnellsburg, 20th; Huntingdon, 20th, 21st; Indiana, 7th, 11th, 20th, 21st, 28th, 29th, 30th, 31st; Lancaster, 20th, 31st; New Castle, 19th, 20th, 21st, 28th, 30th; Lebanon, 20th, 27th, 28th, 31st; Greenville, 6th, 7th, 9th, 11th, 18th, 20th, 21st, 22d, 27th, 28th, 29th, 30th, 31st; New Bloomfield, 20th, 21st, 28th, 31st; Philadelphia, 20th, 28th; Coudersport, 6th, 21st, 22d, 24th, 27th, 28th, 29th, 30th, 31st; Girardville, 20th, 31st; Selins Grove, 20th; Eagles Mere, 9th, 10th, 11th, 20th, 21st, 27th, 28th, 31st; Wellsboro, 7th, 21st, 27th, 28th, 30th, 31st; Westtown, 2cth.

Coronæ.—Charlesville, 8th, 11th, 13th; Reading, 9th; Hollidaysburg, 4th, 8th, 12th; Clarion, 25th; Lebanon, 9th, 10th, 11th, 12th, 14th, 19th, 23d, 24th; Greenville, 17th; Eagles Mere, 13th.

Solar Halos.—Charlesville, 4th; 19th, 23d; Lebanon, 8th; Philadelphia, 4th; Eagles Mere, 8th, 13th, 15th, 19th, 22d, 31st; Wellsboro, 15th, 22d.

Lunar Halos.—Charlesville, 19th; Reading, 19th; Hollidaysburg, 19th; Clarion, 14th, 19th; Carlisle, 20th; Lancaster, 19th; New Castle, 12th, 19th;

Lebanon, 9th; Philadelphia, 15th; Eagles Mere, 19th; Wellsboro, 8th, 15th.

Parhelia—Charlesville, 3d, 19th; Eagles Mere, 24th.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.

Displayman.	*Station.*
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for January, 1889.

Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
Pittsburgh,	847	30·020	30·470	29·010	35·2	61·0	16	17·0	22	42·7	30·3	12·4	29·0	23	4·0	7	74·6	24·7	2·50	5·40	1·00	14	4	8	19	W	W	W	Oscar D Stewart, Sgt. Sig. Corps.
Rochester	821	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Smith Curtis.
Charlesville,	1,300	...	...	...	31·3	59·5	17	−5·0	22	40·4	25·0	15·4	43·0	23	2·0	20	75·1	23·8	3·81	9·50	0·50	9	9	10	12	W	W	W	Rev. A Thos. G. Apple.
Reading,	304	30·063	30·595	29·251	32·1	64·5	17	7·0	23	41·4	25·0	16·4	26·0	23	6·0	27	...	...	3·74	4·50	...	9	12	9	10	NW	NW	NW	C. M. Dechant, C.E.
Kutztown— Keystone State Normal School,	540	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. J. H. Rohrbach.
Altoona,	1,181	...	...	...	37·0	59·0	18	14·0	23	44·8	29·3	15·5	25·0	19	8·0	6	74·3	29·0	1·82	...	...	7	...	...	...	...	...	...	Dr. Charles B. Dudley.
Hollidaysburg,	947	...	...	...	32·0	61·0	17	−2·0	23	41·0	24·0	17·0	42·0	23	8·0	27	84·0	28·0	2·56	6·10	3·00	6	9	11	11	W	W	W	Prof. J. A. Stewart.
Wysox,	718	...	...	...	30·0	59·0	17	0·0	30	36·9	21·4	15·5	32·0	23	3·5	2	83·0	25·0	2·70	8·00	3·00	10	8	4	19	NW	NW	NW	Charles Beecher.
Quakertown,	536	30·040	30·580	29·230	32·4	59·0	17	7·0	23	41·9	24·0	17·9	35·0	23	5·0	27	83·0	27·1	4·58	5·25	...	11	10	13	8	NW	NW	NW	J. L. Heacock.
Butler,		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
Johnstown,	1,184	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. C. Lorentz.
Emporium,	1,030	...	...	...	30·5	56·0	17	−3·0	23	38·2	22·4	15·8	39·0	23	4·0	14	78·0	23·0	2·75	7·50	...	10	5	11	15	W	W	W	T. B. Lloyd
State College— Agricultural Experiment Station,	1,191	30·091	30·676	29·152	30·1	57·0	17	10·0	23	37·2	21·7	15·5	24·0	24	5·0	1	90·2	27·9	1·97	6·61	1·50	7	9	12	10	W	W	W	Prof. Wm. Frear.
Phillipsburg,	1,350	...	...	...	28·3	56·0	17	−1·0	23	35·4	17·2	18·2	47·0	23	4·0	7	...	...	2·41	6·25	2·00	12	4	11	16	SW	SW	SW	Geo. H. Dunkle.
West Chester,	455	30·028	30·573	29·178	34·5	58·0	9	16·0	20	42·1	28·3	13·8	25·0	9	4·0	6	73·0	27·1	4·78	2·50	...	13	16	5	10	NW	NW	NW	Jesse C. Green, D.D S
Coatesville,	380	...	...	...	33·2	61·5	17	13·5	23	44·0	25·2	18·8	32·0	9	5·0	6	...	...	4·33	3·30	...	13	15	5	11	W	W	W	W. T. Gordon.
Westtown,	550	30·130	30·670	29·370	33·0	68·0	17	20·0	20	42·3	29·4	12·9	21·0	17	4·0	5	...	...	3·51	4·00	...	8	9	15	7	W	W	W	
Rimersburg,	1,500	...	...	...	30·0	50·0	17	12·0	28	35·0	24·0	11·0	22·0	13	1·0	7	...	...	...	12·25	4·00	...	3	13	15	SE	SW	E	Rev. W. W. Deatrick, A.M
Clarion— State Normal School,	1,530	...	...	...	29·1	56·5	17	6·5	23	37·6	21·6	16·0	28·5	23	5·5	7	85·0	24·2	3·35	...	...	5	5	12	14	SW	SW	SW	C. M Thomas, B.S.
Grampian Hills,	1,450	...	...	...	28·8	52·0	17	6·0	23	34·4	23·8	10·6	30·0	23	2·0	7	...	...	3·32	17·00	6·50	14	4	13	14	W	W	W	Nathan Moore
Lock Haven,	560	...	...	...	32·0	57·0	17	0·5	23	37·5	22·4	15·1	29·5	23	4·0	7	...	...	3·48	9·00	2·00	6	11	4	16	W	W	W	Prof. John A. Robb.
Catawissa,	491	...	...	...	35·0	62·0	17	11·0	23	41·3	28·0	13·3	29·0	23	3·0	28	...	...	3·22	6·25	2·00	10	10	11	10	W	W	W	Robert M. Graham.
Meadville— Allegheny College,	1,050	30·137	30·615	29·280	30·1	56·5	15	12·0	19	40·9	27·6	13·3	20·0	4	3·0	8	70·1	27·4	4·25	21·00	6·00	13	11	4	16	SW	S	S	R. B. Derickson.
Carlisle,	480	...	...	...	33·2	65·0	17	4·0	23	41·0	27·5	13·5	31·0	23	0·5	5	75·0	27·8	3·49	4·00	...	12	9	10	12	W	W	W	J. E. Pague
Harrisburg,	361	30·086	30·620	29·210	32·6	62·0	17	13·0	23	39·3	25·5	13·8	28·0	17	6·0	27	...	...	3·86	4·50	...	11	7	12	12	NW	NW	NW	Frank Ridgway, Sgt. Sig Corps.
Swarthmore— Swarthmore College,	190	30·041	30·442	29·392	35·7	56·5	16	17·9	20	41·8	28·8	13·0	23·7	23	3·8	6	80·0	29·0	4·80	2·00	...	6	8	10	13	NW	NW	NW	Prof Susan J. Cunningham
Erie,	681	30·020	30·550	29·220	31·0	53·0	16	12·0	20	38·0	27·0	11·0	23·0	16	2·0	28	...	...	2·71	...	...	19	2	11	18	S	S	S	Peter Wood, Sgt Sig. Corps.
Uniontown,	1,000	30·000	30·366	29·157	36·5	62·0	16	13·0	22	46·3	27·5	18·8	40·0	23	6·0	21	79·0	30·0	2·34	...	...	11	7	14	10	SW	W	W	Wm. Hunt.
Tionesta,	1,058	...	...	...	29·5	54·0	17	4·0	23	38·1	24·0	14·1	39·0	23	3·0	8	85·0	25·2	3·50	10·00	4·00	14	5	7	19	W	W	W	Robert L. Haslet.
Chambersburg— Wilson Female College,	618	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	P. C. Richardson.
McConnellsburg,	875	...	...	...	33·0	64·0	17	2·0	23	43·5	26·4	17·1	40·0	23	7·0	27	76·0	26·5	3·53	7·50	...	7	13	7	11	W	W	NW	Thomas F. Sloan.
Huntingdon— The Normal College,	650	...	...	...	32·5	61·0	17	−1·5	23	38·7	23·0	15·7	39·5	23	2·5	7	...	...	2·84	5·00	...	7	8	10	13	W	W	W	Prof. W J. Swigart.
Indiana— State Normal School,	1,350	...	...	...	34·9	59·0	16	8·0	30	41·8	27·5	14·3	30·0	10	4·0	20	89·0	32·1	2·94	8·10	4·00	14	3	9	19	W	W	W	Prof. Albert E Maltby.
Scranton,	750	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J F. Baumeister.
Lancaster— Franklin and Marshall College,	413	30·065	31·068	29·225	34·9	64·0	17	14·5	23	41·9	26·1	15·8	27·5	23	5·5	6	74·8	26·7	2·83	2·50	0·50	11	10	12	9	W	W	W	A M Schmidt, A B.
New Castle,	932	...	...	...	33·2	56·0	17	−2·0	22	39·3	23·2	16·1	38·0	23	5·0	7	89·4	29·8	3·17	10·50	1·00	7	3	7	21	SE	SE	SE	Wm. T Butz.
Lebanon,	480	30·041	30·595	29·205	33·0	62·0	17	11·5	23	...	26·2	...	...	...	...	...	79·8	28·3	4·26	5·20	1·00	11	11	9	11	NE	SW	SW	George W. Hayes C.E., Ph G.
Drifton— Drifton Hospital,	1,655	...	...	...	30·4	60·0	17	7·0	19	41·7	23·0	18·7	36·0	26	7·0	7	...	...	3·74	3·25	...	8	...	...	...	...	...	...	H D. Miller, M.D
Smethport,	1,500	...	...	...	30·0	52·0	17	−1·5	23	35·2	24·1	11·1	48·5	23	3·0	8	80·0	24·0	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
Greenville— Thiel College,	1,000	30·063	30·492	29·982	28·7	54·6	17	9·0	22	38·2	24·0	14·2	36·1	23	4·0	7	89·3	25·8	3·52	7·87	1·50	14	2	8	21	SW	SW	SW	Prof S. H. Miller.
Pottstown,	150	...	...	...	35·0	58·0	17	16·0	23	40·3	29·4	10·9	21·0	4	2·0	5	72·0	27·0	4·12	5·00	...	9	16	9	6	W	SW	W	Charles Moore, D.D.S.
Bethlehem,	360	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Lerch & Rice.
Shamokin,	733	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	G. R. Hanley.
New Bloomfield,	400	...	...	...	31·7	64·0	17	0·0	23	42·4	27·9	19·5	38·0	23	6·0	27	...	...	3·52	8·50	1·00	6	15	5	11	W	W	W	Frank Mortimer.
Philadelphia,	117	30·070	30·630	29·190	37·3	59·0	17	18·0	20	45·0	32·0	13·0	24·0	9	5·0	6	72·0	28·6	3·75	1·75	...	11	14	6	11	W	W	NW	Luther M. Dey, Sgt. Sig Corps
Coudersport,	1,670	...	...	...	28·6	50·0	4	−2·0	23	36·4	20·5	15·9	43·0	24	10·0	2	78·2	22·3	4·80	17·50	6·00	11	11	5	14	W	W	W	C. L. Peck.
Girardville,	1,000	30·070	30·575	29·444	32·7	51·0	9	1·0	21	40·0	24·0	16·0	33·0	25	5·0	8	...	...	3·80	9·00	3·00	9	14	7	10	NW	NW	NW	E. C Wagner.
Selins Grove,	445	...	...	...	33·3	55·0	17	8·0	23	39·1	29·1	10·0	27·0	23	1·0	7	79·1	27·1	4·00	7·50	...	8	5	12	14	NW	NW	NW	J M Boyer.
Somerset,	2,250	...	...	...	30·7	54·0	4	7·5	23	39·5	23·4	16·1	29·0	31	4·0	7	86·0	27·2	3·48	12·75	4·00	4	...	...	...	...	...	...	W. M. Schrock.
Eagles Mere,	2,060	30·112	30·615	29·277	26·6	50·0	17	−1·0	20	32·2	21·2	11·1	26·0	20	2·0	6	71·1	19·0	4·92	19·25	8·50	10	8	9	14	SW	SW	SW	E. S. Chase.
Montrose,	1,656	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A H Berlin.
Wellsboro,	1,327	30·015	30·605	29·186	29·7	58·0	17	−2·0	23	37·8	23·9	13·9	20·4	19	4·6	16	80·9	24·5	7·02	12·40	4·20	14	4	8	19	S	SW	SW	H. D Deming
Franklin,		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. N. P. Kinsley.
Columbus,	1,410	30·016	30·735	29·354	29·2	50·0	17	4·0	23	25·9	22·5	13·4	42·0	23	2·0	7	...	...	3·22	6·00	2·00	...	...	...	...	...	...	...	Wm. Loveland.
Dyberry,	1,100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Theodore Day.
Honesdale,	1,000	...	...	...	27·8	54·0	17	−3·0	23	35·1	20·6	14·5	36·0	23	4·0	7	...	...	4·15	...	5·50	11	...	...	...	...	...	...	John Torrey.
Greensburg,	1,075	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H S. Brunot.
York,	385	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PRECIPITATION FOR JANUARY, 1889.

	Erie.	Greenville.	New Castle.	Meadville.	Columbus.	Pittsburgh.	Clarion	Uniontown.	Indiana.	Somerset.	Grampian Hills.	Emporium.	Phillipsburg.	Huntingdon.	Hollidaysburg.	Altoona.	Charlesville.
1					.01									.03			
2																	
3																	
4																	
5	.10	.52	.12	.58		.38		.16		.55		.18	.20	.30	.57	.24	1.12
6	.28	.27		.28	.60	.07		.07	.40	.18	.80	.39	.80	.44	.19	.42	.29
7	.05	.02	.55	.16	.06	.06	.64		.01		.06	.02	.02				
8									20								
9	.08	.39	.37	.95	.37	.29	.52	.28	.15	.58	.35	.30	.20	.62	.37	.25	.71
10	.04				.03											.08	
11	[illegible]	.05	.03		.09	.02	.05				.02		.01				
12	.02					.01			.05				.02				
13	.02																
14								.05									
15				.11													
16	.06	.34	.35	.20	.35	.17	.29		.20								.07
17	.04	.04				.05		.22			.34	.28	.18	16			.15
18	01	.01		.20	.02												
19	.03																
20	.07	.70		.30	.18	.20			.15	.50		.50			.80		.67
21	.08	[illegible]		.45	.05	.20		.13	.20	.30	.66		.36	.59		.45	.21
22													.02				
23																	
24	.04		.30		.16	.09		.03	.43		.10	.11					
25						.01											
26								.12		.43					.04		.06
27	.82	[illegible]	1.45		1.00	.71		.98	.75	.48	.55	.64	.32	.70	.59	.01	.53
28	[illegible]	[illegible]		.35	.10	.13		.04	.05	.30	.18	.18	.26			.35	
29	[illegible]			.15	.03	.04	1.85		.15	.12			.02				
30				.47					.10		.04						
31				.05	.17	.07		.26	.10	.04	.22	.15					
	2.71	[illegible]	[illegible]	4.25	3.22	2.50	3.35	2.34	2.94	3.48	3.32	2.75	2.41	2.84	2.56	1.82	3.81

	State College.	McConnellsburg.	Lock Haven.	New Bloomfield	Carlisle.	Wellsboro.	Harrisburg.	Selins Grove.	Wysox.	Eagles Mere.	Catawissa.	Girardville.	Lebanon.	Lancaster	Drifton.	Reading.	Pottstown.
1			.02														
2																	
3																	
4																	
5		.81	.82	.75	.33	.60	.34	.80	.93	.76	.16	.39	.39	.39	.90	.56	.40
6	.78	.19	1.00	1.05	.85	1.40	.38	1.00	.28		.70	.36	.20	.09	.42		.22
7						.05	.02		.05						.08	.51	
8																	
9	.33	.65	.38	.75	.43	1.64	.61	.90	.41	.86	.83	.95	.90	.44	.82	.72	.65
10					.07					.11							
11	.02																
12																	
13																	
14																	
15									.03								
16				.15		.40	.10	.10		.51	.10	.31	.17	.08	.76	.17	.40
17		.40	.08	.02	.55		.52	.30			.34	.62	1.08	.47	.15	.37	.15
18	.09																
19																	
20		.75			.01		.22		.42	1.19	.33	.63	.47	.32	.24	.50	1.60
21	.20				.71	1.16	.06						.43	.48		.53	
22																	
23																	
24						.05								.10		.02	.20
25																	
26		.06			.02	.30	.10	.10	.09		.01	.08	.03	.05			
27	.50	.42	1.18	.80	.34	1.10	.42	.70	.38	.59	.45	.32	.44	.31	.37	.36	.45
28					.04	.10	.01	.10	.10	.54	.10		.04				
29					.05				.01								
30						.02											
31	.05	.25			.09	.20	.08			.36	.20	.14	.11	.10			.05
	1.97	.53	3.48	3.52	3.49	7.02	2.86	4.00	2.70	4.92	3.22	3.80	4.21	2.83	3.74	3.74	4.12

	West Chester	Coatesville	Honesdale.	Quakertown.	Swarthmore	Philadelphia.	Coudersport.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y	Germantown.	Point Pleasant
1			.01													
2																
3																
4																
5	.93	.71	.50	.46		.41										
6	.23	.27	.82	.44	.73	.15	.60	.69	.47	.74	.87	.98	.38	.52	.49	77
7		.01	.05	.01												
8																
9	.72	.77	.44	.83	.54	.52	.60	.75	.69	.61	.73	.57	.66	.58	.66	.71
10																
11																
12																
13																
14																
15																
16	.11	.05		.16		.08	.40									
17	.81	.62	.47	1.01	1.34	.95		1.23	.72	1.04	.85	.63	.71	.65	1.28	.90
18																
19																
20	.55	.62	.98	.50	1.44	.18				1.41						
21	.60	.69		.51		.90	.70	1.19	.98		1.05	1.53	.78	1.29	.94	1.65
22							.20									
23																
24	.10	.10	.01	.07		.06	.10	.03	.10		.07	.06	.09	.05		
25	.03	.02			.17	.09										
26	.02	.02				.02										
27	.62	.44	.78	.58	.58	.38	1.50	.39	.44	.50	.58	.55	.30	.46	.42	.55
28	.03	.01		.01												
29			.03				.50									
30																
31	.03		.06				.20		.04		04		.03		.03	.06
	4.78	4.33	4.15	4.58	4.80	3.75	4.80	4.28	3.44	4.30	4.19	4.32	2.95	3.55	3.82	4.64

T. F. T.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR FEBRUARY, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 28, 1889.

TEMPERATURE.

The mean temperature for February, obtained from the daily observations of forty-six stations, was 23°·0, which is 6° below the normal.

The mean daily maximum and minimum, 31°·3 and 14°·8 respectively, give a monthly mean of 23°·0.

Uniontown reports an average daily temperature of 30°·0, and Eagles Mere 12°·0, which are the two extremes.

The highest temperatures reported were Indiana, 60°; Uniontown, 58°; McConnellsburg and Phillipsburg each 56°. The lowest were Coudersport, minus 27°; Smethport, minus 27°; Columbus, minus 26°; Grampian Hills, minus 21°; Clarion, minus 21°; Emporium, 20°, and Wellsboro, minus 20°.

The low temperature occurred on the 24th.

BAROMETER.

The mean pressure for the month, 30·14, is ·05 above the normal. The highest pressure occurred during the cold period of the 24th, and the lowest on the 5th and 18th. Rain and snow storms attended these depressions.

PRECIPITATION.

The amount of rain and melted snow for the month averaged 1·96 inches, which is 1·25 inches less than the normal. The precipitation was evenly distributed throughout the state, and at quite regular intervals during the month. Snows were numerous, but soon melted in the agricultural districts. The greatest total snow falls in inches for the month were Eagles Mere, 28;

Smethport, 20; Phillipsburg, 18; Wellsboro, 18; Coudersport, 17, and Grampian Hills, 17. No heavy drifts occurred.

WIND AND WEATHER.

The prevailing wind was from the west. No severe gales occurred. Owing to the rapid melting of the snows, winter grain has been much exposed, but at the end of the month it had not been materially injured. The ice harvest was abundant.

Average number.—Rainy days, 9; clear days, 7; fair days, 9; cloudy days, 12.

MISCELLANEOUS PHENOMENA.

Snow.—Charlesville, 3d, 4th, 5th, 6th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 18th, 23d, 24th, 25th, 26th; Reading, 2d, 3d, 4th, 25th, 27th; Hollidaysburg, 2d, 3d, 5th, 6th, 7th, 8th, 11th, 18th, 26th; Wysox, 5th, 8th, 12th, 17th, 26th, 27th; Quakertown, 4th, 5th, 6th, 9th, 11th, 12th, 23d, 25th, 27th, 28th; Emporium, 1st, 5th, 8th, 9th, 11th, 16th, 18th, 27th; Phillipsburg, 1st, 2d, 3d, 4th, 5th, 6th, 7th, 10th, 11th, 12th, 13th, 14th, 15th, 20th, 24th, 26th, 28th; West Chester, 5th, 6th, 11th, 23d, 24th, 25th, 27th; Coates, ville, 11th, 12th, 25th, 27th; Westtown, 5th, 11th, 25th, 28th; Rimersburg, 2d, 3d, 5th, 8th, 9th, 11th, 12th, 18th, 22d, 25th, 26th; Clarion, 2d, 3d, 5th, 8th, 11th, 12th, 18th, 26th; Grampian Hills, 2d, 5th, 7th, 11th, 16th, 18th, 26th; Lock Haven, 5th, 8th, 9th, 11th, 16th, 18th, 26th, 27th; Catawissa, 8th, 16th, 25th, 26th; Meadville, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 21st, 26th, 27th; Carlisle, 9th, 11th, 27th; Swarthmore, 11th, 22d, 27th; Uniontown, 4th, 11th, 12th, 13th; McConnellsburg, 8th, 9th, 10th; Huntingdon, 11th, 27th; Indiana, 1st, 5th, 8th, 10th, 11th, 18th; Lancaster, 5th, 11th, 25th, 27th; New Castle, 8th, 12th, 18th, 23d, 26th; Lebanon, 3d, 4th, 5th, 9th, 11th, 12th, 25th, 27th; Drifton, 8th, 16th, 22d, 27th; Smethport, 1st, 2d, 3d, 5th, 8th, 9th, 10th, 11th, 12th, 16th, 17th, 18th; Greenville, 1st, 3d, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 18th, 22d, 25th, 26th, 27th; Pottstown, 11th, 12th, 27th; Bethlehem, 5th, 8th, 12th, 16th, 18th, 27th; New Bloomfield, 8th, 9th, 11th, 27th; Coudersport, 2d, 3d, 8th, 9th, 10th, 11th, 12th, 18th, 27th; Girardville, 5th, 8th, 11th, 23d, 24th, 26th, 27th; Selins Grove, 8th, 11th, 26th, 27th; Somerset, 3d, 4th, 5th, 9th, 10th, 11th, 13th, 18th, 22d, 25th, 26th, 27th; Eagles Mere, 1st, 2d, 3d, 5th, 8th, 9th, 10th, 11th, 12th, 18th, 22d, 26th, 27th, 28th; Wellsboro, 1st, 2d, 3d, 4th, 5th, 6th, 8th, 11th, 12th, 16th, 17th, 18th, 22d, 26th, 27th; Columbus, 1st, 2d, 5th, 6th, 7th, 8th, 10th, 11th, 12th, 13th, 18th, 22d, 26th, 27th; Philadelphia,

Coronæ.—Charlesville, 9th; Hollidaysburg, 13th; Catawissa, 13th; Huntingdon, 10th; Lebanon, 6th, 7th, 9th, 10th, 12th, 13th, 14th, 15th; Greenville, 10th, 13th, 14th.

Solar Halos.—Charlesville, 21st; West Chester, 26th; Girardville, 24th; Eagles Mere, 13th, 24th, 26th.

Lunar Halos.—Charlesville, 7th, 10th, 13th, 14th; Reading, 13th; Hollidaysburg, 10th; West Chester, 10th; Carlisle, 9th, 10th; Lancaster, 13th;

Lebanon, 13th; Greenville, 10th, 14th; Selins Grove, 14th; Somerset, 10th, 14th; Eagles Mere, 13th.

Parhelias.—Eagles Mere, 15th, 24th, 25th.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.

Displayman.	*Station.*
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for February, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer.			Temperature.												Relative Humidity.	Dew Point.	Precipitation.				Number of Days.			Wind.			Observers.
			Mean.	Highest.	Lowest.	Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.			Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	Prevailing Direction. 7 A. M.	Prevailing Direction. 2 P. M.	Prevailing Direction. 9 P. M.	
…gheny,[1]	Pittsburgh,	847	30·118	30·750	29·370	27·3	53·0	17	−1·0	24	34·9	21·2	13·7	32·0	5	6·0	6	72·6	19·2	1·58	...	...	16	1	12	15	W	W	W	Oscar D. Stewart, Sgt. Sig. Corps.
…aver,	Rochester	821	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Smith Curtis.
…dford,	Charlesville,	1,300	...	...	...	24·0	51·0	17	−9·0	24	32·5	16·7	15·8	35·0	23	4·0	28	72·5	15·9	1·53	3·80	...	10	4	10	14	NW	W	SW	Rev. A. Thos. G. Apple.
…rks,[1]	Reading,	304	30·202	30·765	29·615	24·5	43·5	5	−4·0	24	35·5	17·3	18·2	34·0	23	5·0	18	...	...	1·36	1·00	...	7	12	7	9	NW	NW	NW	C. M. Dechant, C.E.
…rks,	Kutztown—																													
	Keystone State Normal School,	540	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. J. H. Rohrbach.
…air,[2]	Altoona,	1,181	...	...	...	30·0	51·0	18	−3·0	24	39·1	20·9	18·2	34·0	23	7·0	3	69·8	21·5	1·24	...	...	9	...	...	...	...	...	...	Dr. Charles B. Dudley.
…air,	Hollidaysburg,	947	...	...	...	24·0	49·0	22	−7·0	24	33·0	15·0	18·0	34·0	21	5·0	6	81·0	19·0	1·91	5·75	...	5	13	5	10	W	W	W	Prof. J. A. Stewart.
…dford,	Wysox,	718	...	...	...	17·1	44·0	17	−15·0	24	27·0	10·4	16·6	30·1	21	2·5	7	81·3	15·2	1·73	14·00	6·00	8	6	10	12	NW	NW	NW	Charles Beecher.
…cks,	Forks of Neshaminy,	...	...	...	...	22·3	44·0	17	3·0	24	...	...	...	...	...	...	...	...	...	2·03	...	...	7	...	...	...	W	NW	W	
…cks,	Point Pleasant,	...	...	...	...	22·2	34·5	17, 18	3·5	24	...	...	...	...	...	...	...	...	...	2·20	...	...	8	...	...	...	...	...	...	
…cks,	Quakertown,	536	30·120	30·820	29·460	24·3	40·0	17	−4·5	24	34·3	15·4	18·9	28·7	21	7·5	18	83·8	15·3	2·38	1·69	...	11	6	12	10	NW	NW	NW	J. L. Heacock.
…tler,	Butler,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
…mbria,	Johnstown,	1,184	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. C. Lorentz.
…meron,	Emporium,	1,030	...	...	...	21·8	45·0	22	−20·0	24	31·3	8·5	22·8	50·0	21	7·0	23	...	...	1·61	13·35	7·00	8	3	14	11	W	W	W	T. B. Lloyd.
…ntre,	State College—																													
	Agricultural Experiment Station,	1,191	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Wm. Frear.
…ntre,	Phillipsburg,	1,350	...	...	...	18·5	56·0	22	−19·0	24	30·0	8·0	22·0	44·0	21	6·0	28	...	...	1·87	17·75	2·00	19	8	4	16	SW	SW	SW	Geo. H. Dunkle.
…ester,	West Chester,	455	30·156	30·823	29·430	26·3	44·0	5, 7	−2·0	24	26·6	19·3	7·3	25·5	23	2·0	28	70·0	17·8	2·46	3·50	1·00	12	12	8	8	W	W	W	Jesse C. Green, D.D.S.
…ester,	Coatesville,	380	...	...	...	25·6	49·0	17	−3·0	24	35·2	18·1	17·1	28·5	21	6·0	18	...	...	1·85	4·60	1·00	9	10	6	12	W	W	W	W. T. Gordon.
…ester,[1]	Westtown,	550	30·250	30·900	29·630	25·4	47·0	5, 17	2·0	24	35·8	21·0	14·8	25·0	23	7·0	18	...	...	1·72	5·50	1·00	9	12	8	8	W	W	W	
…rion,	Rimersburg,	1,500	...	...	...	20·2	42·0	22, 28	−13·0	24	27·2	12·7	14·5	28·0	22	4·0	27	...	...	...	15·50	2·00	11	0	16	12	SW	W	NW	Rev W. W. Deatrick, A.M.
…rion,	Clarion—																													
	State Normal School,	1,530	...	...	...	20·0	46·5	17	−21·0	24	29·2	11·4	17·8	34·1	21	2·5	14	84·3	15·0	2·10	...	...	...	...	...	...	SW	SW	SW	C M Thomas, B.S.
…arfield,	Grampian Hills,	1,450	...	...	...	18·2	42·0	22	−24·0	24	25·3	11·1	14·2	40·0	21	2·0	17	...	...	1·96	17·00	12·00	7	4	10	14	W	W	W	Nathan Moore.
…nton,	Lock Haven,	560	...	...	...	22·0	49·0	22	−11·0	24	29·8	11·1	18·7	34·0	14	8·0	28	...	...	1·74	9·50	...	9	12	5	11	N	W	W	Prof. John A. Robb.
…umbia,	Catawissa,	491	...	...	...	26·7	48·5	22	−5·0	24	32·3	17·8	14·5	28·5	15	4·0	1	76·3	20·8	1·61	6·50	...	9	10	8	10	N	NW	W	Robert M. Graham.
…awford,	Meadville—																													
	Allegheny College,	1,050	...	...	...	23·2	45·0	10	−9·0	24	25·0	12·6	12·4	21·0	15	1·5	23	...	...	2·85	9·75	1·00	11	9	8	11	W	W	W	R. B. Derickson.
…mberland,	Carlisle,	480	...	...	...	26·1	42·5	9	0·0	24	32·9	20·2	12·7	30·0	9	1·5	16	69·0	19·0	1·68	4·25	...	11	4	12	12	W	W	W	J. E. Pague.
…uphin,[1]	Harrisburg,	361	30·194	30·860	29·640	25·0	44·0	17	−1·0	24	31·2	19·2	12·0	21·0	21	3·0	12	...	...	1·48	...	...	...	9	5	14	NW	NW	NW	Frank Ridgway, Sgt. Sig. Corps.
…aware,	Swarthmore—																													
	Swarthmore College,	190	30·185	30·742	29·505	28·1	47·8	5	0·5	24	35·7	21·5	14·2	25·1	23	6·7	18	79·0	21·0	1·92	1·70	1·00	5	3	8	17	...	...	...	Prof Susan J. Cunningham.
…e,[1]	Erie,	681	30·120	30·800	29·330	21·0	54·0	16	−10·0	24	29·0	14·0	15·0	32·0	5	3·0	1	...	...	1·57	...	...	20	3	7	18	...	...	...	Peter Wood, Sgt Sig. Corps.
…ette,	Uniontown,	1,000	30·070	30·599	29·414	30·0	58·0	16	−1·0	24	36·2	19·8	17·4	26·0	16	6·0	28	73·0	22·0	2·43	6·00	...	7	6	12	[illegible]	NW	NW	NW	Wm. Hunt.
…est,	Tionesta,	1,058	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Robert L. Haslet.
…anklin,[1]	Chambersburg—																													
	Wilson Female College,	618	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	P. C. Richardson.
…ton,	McConnellsburg,	875	...	...	...	20·4	56·0	17	2·0	24	36·7	19·2	17·5	40·0	23	5·0	16	80·0	20·7	1·65	2·50	...	6	8	9	11	N	NW	NW	Thomas F. Sloan.
…ntingdon,	Huntingdon—																													
	The Normal College,	650	...	...	...	24·0	41·0	18	−8·0	24	28·9	13·6	15·3	29·0	8	4·0	6	...	...	·97	3·20	...	4	6	14	8	W	W	W	Prof. W J. Swigart.
…iana,	Indiana—																													
	State Normal School,	1,350	...	...	...	26·4	60·0	18	−11·0	24	32·9	18·5	13·4	32·0	21	2·0	20	84·5	22·6	2·42	4·10	...	10	4	9	[illegible]	W	W	W	Prof. Albert E Maltby.
…ckawanna,	Scranton,	750	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. F. Baumeister.
…ncaster,	Lancaster—																													
	Franklin and Marshall College,	413	30·164	30·815	29·457	26·4	44·0	3, 9	−1·5	24	34·4	18·9	15·5	26·5	23	7·0	16	70·0	17·4	2·16	4·00	...	8	7	9	[illegible]	W	W	W	A. M. Schmidt, A.B.
…wrence,	New Castle,	932	...	...	...	24·7	50·0	17	−11·0	24	32·7	14·5	18·2	37·0	5	5·0	27	88·2	20·2	3·33	10·75	...	6	7	7	14	NW	NW	NW	Wm. T Butz.
…banon,	Lebanon,	480	30·167	30·847	29·471	25·8	44·8	22	0·0	24	34·2	19·2	15·0	32·4	23	4·1	18	75·7	19·0	1·85	5·50	...	11	6	13	9	SW	NW	NE	George W. Hayes, C.E., Ph G.
…zerne,	Drifton—																													
	Drifton Hospital,	1,655	...	...	...	18·7	47·0	...	−13·0	...	32·0	10·1	21·9	33·0	...	11·0	...	...	...	1·46	8·50	...	5	...	...	...	...	...	...	H. D. Miller, M.D.
…Kean,	Smethport,	1,500	...	...	...	20·8	43·0	22	−27·0	24	28·8	8·1	20·7	47·0	21	5·0	6	...	...	2·72	19·75	...	12	3	7	18	SW	SW	SW	Armstrong & Brownell.
…ercer,[1]	Greenville—																													
	Thiel College,	1,000	30·087	30·811	29·295	19·1	48·9	17	−16·8	24	30·8	11·3	19·5	40·6	24	2·7	1	89·7	16·0	1·18	14·00	...	13	5	16	7	NW	NW	SW	Prof S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	23·5	44·0	9	0·0	24	33·0	21·0	12·0	26·0	14	1·0	18	69·0	15·0	1·92	2·00	...	6	13	6	9	NW	W	W	Charles Moore, D.D.S.
…rthampton,	Bethlehem,	360	...	...	...	27·0	42·0	17	−1·0	24	33·0	19·0	14·0	39·0	22	9·0	24	71·0	20·0	1·94	4·00	...	6	10	5	[illegible]	W	NW	W	Lerch & Rice.
…humberland,	Shamokin,	733	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	G. R Hanley.
…rry,	New Bloomfield,	400	...	...	...	22·3	51·0	17	0·5	24	32·2	14·0	18·2	36·0	2	6·0	28	...	...	1·24	6·30	0·50	7	13	7	8	W	W	W	Frank Mortimer.
…ladelphia,[1]	Philadelphia,	117	30·180	30·800	29·450	28·2	51·0	5	2·0	24	35·9	23·1	12·8	22·0	5	5·0	19	68·6	18·6	2·00	3·40	...	10	3	12	13	NW	NW	NW	Luther M. Dey, Sgt. Sig Corps.
…ter,	Coudersport,	1,670	...	...	...	17·8	44·0	12, 22	−27·0	24	25·5	8·8	16·7	51·0	21	4·0	3	78·2	12·1	1·90	16·50	8·00	7	5	10	[illegible]	W	W	W	C. L. Peck.
…uylkill,	Girardville,	1,000	30·214	30·776	29·845	23·1	41·0	17	−4·0	24	30·0	15·2	14·8	22·0	21	8·0	17	...	...	1·66	12·00	3·00	9	12	7	[illegible]	NW	NW	NW	E. C. Wagner.
…der,	Selins Grove,	445	...	...	...	24·8	46·0	17	−4·0	24	32·7	11·8	20·9	28·0	14	2·0	19	80·0	19·0	1·52	2·80	1·00	4	12	9	7	SW	SW	SW	J M Boyer,
…merset,	Somerset,	2,250	...	...	...	21·0	50·0	17	−13·0	24	33·5	13·3	20·2	33·0	24	3·0	6	83·0	18·9	3·13	15·70	3·00	15	6	12	10	NW	NW	NW	W. M. Schrock.
…livan,	Eagles Mere,	2,060	30·198	30·892	29·554	12·0	40·0	17	−17·0	24	23·2	8·8	14·4	29·0	23	3·0	3	61·7	6·5	3·87	28·50	23·00	9	6	10	12	SW	SW	SW	E. S. Chase.
…quehanna,	Montrose,	1,656	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A H. Berlin.
…ga,	Wellsboro,	1,327	30·093	30·841	29·399	18·4	54·0	17	−20·0	24	30·2	10·2	20·0	33·1	26	3·2	14	80·5	13·5	2·98	17·55	12·50	15	3	7	18	SW	W	W	H. D. Deming.
…nango,	Franklin,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. N. P. Kinsley.
…rren,	Columbus,	1,410	...	...	...	18·4	42·0	15	−26·0	24	27·1	9·7	17·4	44·0	4	1·0	17	...	...	1·53	...	4·00	13	4	7	17	SW	SW	SW	Wm. Loveland.
…ayne,	Dyberry,	1,100	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Theodore Day.
…ayne,	Honesdale,	1,000	...	...	...	16·0	39·0	17, 28	−15·0	24	26·6	6·3	20·3	34·0	8	6·0	19	...	...	2·10	...	...	11	...	...	...	...	...	...	John Torrey.
…tmoreland,	Greensburg,	1,075	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H S. Brunot.
…rk,[1]	York,	385	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

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PRECIPITATION FOR FEBRUARY, 1889

	Erie	Greenville	New Castle	Columbus	Pittsburgh	Uniontown	Indiana	Somerset	Grampian Hills	Emporium	Phillipsburg	Huntingdon	Hollidaysburg	Altoona	Charlesville	McConnellsburg	Lock Haven
1	.02			.06	.02		.01	.15		.04	.14						
2	.06			.03					.12		.01			.03			
3	.08				.03			.06							.01		
4					.01	.11		.03			.02						
5		.02	2.00	.16	.14	.21	.05	.05	.24	.20	.03		.10	.02	.02		.55
6	.14				.01						.10						
7	.03	.01			.01												
8	.08	.14	.15	.14	.10	.12	.10	.45	.23	.08	.01				.07	.10	.10
9	.06	.10						.09		.10	.13			.06	.02	.15	.05
10	.05	.13		.25			.20										
11	.06	.17		.20	.09		15	.25	.25	.19	.02	.34	.53	.14	.08		.10
12	.14		.40	.08	.03			.22			.11		.05	.04	.01		
13				.04	.01						.01						
14						.16		.07									
15																	
16	.06	.20		.15	.35	.70	1.60	.60	.44	.15	.15	.09	.58		.51	.65	.02
17	.02				.02		.10	.15			.40			.43	.34	.24	.47
18	.23	.10	.15	.15	.67	.76	.15	.76	.56	.74	.50	43	.65	.44	.42	.44	.20
19	.04										.05			.03			
20	.12																
21																	
22	.09	.05		.03													
23	.04		.30		.03			.07			.02						
24																	
25	.01	.01			.01			.03			.03						
26	.07	.02		.11			.01		.12		.01						.10
27	.17	.21	.33	.13	.05	.37	.05	.15		.11	.06	.11		.05	.05	.07	.15
28		.01									.05						
29																	
30																	
31																	
	1.57	1.18	3.33	1.53	1.58	2.43	2.42	3.13	1.96	1.61	1.87	.97	1.91	1.24	1.53	1.65	1.74

	New Bloomfield	Carlisle	Wellsboro	Harrisburg	Selins Grove	Wysox	Eagles Mere	Catawissa	Girardville	Lebanon	Lancaster	Drifton	Reading	Bethlehem	Pottstown	West Chester
1			.05													.01
2			.05				.28									
3			.05	01						.01						
4		.01	.02							.01						.01
5	.20	.07	.30	.08	.23	.15	.74	.04	.28	.20	.10		.24	.23	[illegible]	.14
6		.07	.02										.02			.05
7																
8	10		.12		.15	.19	.35	.20	.09			.27		.02		
9	.06	.08		.03						.03						
10																
11	.42	.10	.27	.08	.21		.74	.16	.12	13	.11		.03		.05	.14
12		.05	.15			.05				.01				.08	.07	.03
13																
14																
15																
16	06	.15	.20	.20	.74	.30	.46	.54	.63	.67	.60	.45	.75	83	.80	.98
17		.40	.05	.22		.53		.01		.06	.21	.26	.03			.05
18	35	.60	1.52	.71	.15	.10	.38	.24	.31	.50	.30		.40	.56	.4	.61
19																
20																
21																
22			.05				.12					.14				
23									.03							
24									.04							
25				.01				.15		.01	.50					.07
26			.03			.37	.34	.10	.05							
27	.05	.10	.10	.14		.04	.46	.17	.11	.22	.24	.34	.15	.22	.40	.32
28		.05			.04						.01					.05
29																
30																
31																
	1.24	1.68	2.98	1.48	1.52	1.73	3.87	1.61	1.66	1.85	2.16	1.46	1.62	1.94	1.92	2.46

	Westtown	Coatesville	Honesdale	Quakertown	Swarthmore	Philadelphia	Coudersport	Scisholtzville	Frederick	Ottsville	Smith's Corner	Doylestown	Lansdale	Forks of Nesham'y	Germantown	Point Pleasant
1	.01															
2							.30									
3			.01							.13	.03					.02
4												.14				
5	.04	.20	.20	.23		.08		.33	.19	.22	.20		.36	.12	.06	.19
6		.02		.05	.12									.02	.14	
7										.27						
8			.23				.20		.06							
9				.07			.30				.06					.01
10																
11		.10	.18	.07		.14	.10	.23	.10	.17	.16	.22	.11	.17	.20	.19
12	.03	.01	.07	.04			.30									
13																
14																
15																
16	.88	.62	.65	.92	.98	.93		.29	.76	.96	.95	.87	.48	.88		.96
17		.04	.07	.10	.02	.01			.42							
18	.50	.40	.34	.57	.53	.42	.60	1.02		.48	.56	.52	.69	.50	1.29	.58
19																
20																
21																
22						.05										
23																
24						.01										
25		.10	.02	.04		.05		.01	.03	.19			.01	.06	.07	.01
26																
27		.36	.27	.21		.28	.10	.25								
28	.26		.06	.08	.27	.03			.28	.25	.26	.30	.03	.28	.43	.24
29																
30																
31																
	1.72	1.85	2.10	2.38	1.92	2.00	1.90	2.13	1.84	2.67	2.22	2.05	1.63	2.03	2.19	2.20

T. F. T.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR MARCH, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 31, 1889.

TEMPERATURE.

The mean temperature for March, 1889, 38°·9, is from 2° to 3° above the normal, and 7°·8 above that of March, 1888.

The mean, determined from the daily maxima and minima, is 39°·0.

The following stations report the highest average daily temperatures: New Castle, 45°·3; Selins Grove, 44°·0; Indiana, 43°·2, and Pottstown, 43°·0. The highest temperatures noted on any one day were Columbus, 76°·0; Pittsburgh, 70°·0, and Rimersburg, 70°·0. The lowest were Columbus, 4°·0; Somerset, 9°·0; New Castle, 9°·0, and Clarion, 9°·0. The coldest day of the month was on the 30th, but the low temperatures that generally occur in March were not reached. The entire month has been characterized by mildness.

BAROMETER.

The mean barometer, 29·95, is about ·07 below the average. The highest pressure occurred on the 1st, and the lowest on the 7th.

PRECIPITATION.

The average precipitation (rain and melted snow), 2·90 inches, is a deficiency of a little over one-half inch. The distribution was uneven. The largest totals reported for the month were West Chester, 5·44 inches; McConnellsburg, 4·76 inches; Coatesville, 4·49 inches, and Ottsville, 4·42 inches. Several stations report less than 2 inches.

The greatest total snowfall in inches were Charlesville, 11·50; Eagles Mere, 9·60; Girardville, 8·00, and Somerset, 7·80.

Very few stations reported snow on the ground at the end of the month.

WIND AND WEATHER.

The prevailing wind direction was from the northwest.

The weather for March was unusually fine. Notwithstanding the lack of snow, winter grain appears to have been injured very little. Frosts were numerous, but caused little damage.

Average number.—Rainy days, 9; clear days, 10; fair days, 8; cloudy days, 13.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Charlesville, 31st; Quakertown, 27th; Grampian Hills, 31st; Carlisle, 27th; Erie, 31st; McConnellsburg, 27th, 31st; Huntingdon, 31st; Lancaster, 27th; Pottstown, 27th; New Bloomfield, 31st; Girardville, 27th; Somerset, 31st.

Snow.—Charlesville, 3d, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 21st; Wysox, 7th, 9th, 20th, 29th; Emporium, 21st, 22d, 29th, 31st; Phillipsburg, 3d, 10th, 21st, 22d; West Chester, 21st, 30th, 31st; Coatesville, 10th, 21st, 28th, 30th, 31st; Rimersburg, 3d, 6th, 8th, 9th, 10th, 21st, 22d, 28th, 29th; Grampian Hills, 21st, 22d; Lock Haven, 21st, 31st; Catawissa, 29th, 31st; Carlisle, 31st; Uniontown, 9th, 10th, 28th, 30th; Lancaster, 8th, 20th, 21st, 30th, 31st; New Castle, 10th, 19th; Lebanon, 9th, 10th, 21st, 31st; Pottstown, 29th, 31st; New Bloomfield, 31st; Philadelphia, 8th, 9th, 10th, 21st, 30th, 31st; Girardville, 9th, 20th, 21st, 29th, 31st; Selins Grove, 8th, 9th, 10th, 21st, 29th, 31st; Somerset, 3d, 4th, 6th, 9th, 10th, 21st, 29th; Eagles Mere, 4th, 8th, 9th, 10th, 29th, 31st; Wellsboro, 21st, 29th, 31st; Columbus, 7th, 8th, 9th, 28th, 29th, 30th, 31st; Dyberry, 20th, 21st, 31st.

Coronæ.—Hollidaysburg, 3d, 7th, 8th, 9th, 19th, 21st, 29th; Rimersburg, 16th; Indiana, 14th; Eagles Mere, 13th; Dyberry, 16th.

Solar Halos.—Eagles Mere, 1st, 15th, 18th, 27th; Dyberry, 15th.

Lunar Halos.—Hollidaysburg, 15th; Quakertown, 14th; Rimersburg, 14th, 15th; Clarion, 14th, 15th; Grampian Hills, 14th; Erie, 8th, 15th; McConnellsburg, 14th; Lancaster, 14th; Philadelphia, 10th, 14th; Girardville, 14th, 15th; Somerset, 14th, 15th; Eagles Mere, 15th; Dyberry, 14th.

Parhelia.—Dyberry, 19th.

Earthquake.—Coatesville, 8th; Lancaster, 8th; Selins Grove, 8th; York, 8th.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.

Displayman.	*Station.*
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for March, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Snowfall During Month.	Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
Allegheny,[1]	Pittsburgh,	847	29·935	30·390	29·470	41·4	70·0	31	23·0	30	51·3	35·1	16·2	36·0	31	5·0	19	65·8	29·6	2·32	...	15	6	10	15	NW	NW	W	Oscar D Stewart, Sgt. Sig. Corps.
Beaver,	Rochester	821	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Smith Curtis.
Bedford,	Charlesville,	1,300	...	...	...	39·2	67·5	31	19·5	12	50·4	28·8	21·6	41·0	13	4·5	18	77·1	28·4	4·16	11·50	7	...	...	...	NW	NW	NW	Rev. A Thos. G. Apple.
Berks,[1]	Reading,	304	29·929	30·489	29·380	38·9	69·0	14	22·5	30	51·3	31·8	19·5	40·0	14	4·0	4	86·6	34·7	3·71	3·50	9	11	5	15	NW	NW	SW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	42·7	65·0	19	22·0	30	51·5	33·9	17·6	34·0	30	9·0	5	[illegible]	30·0	2·37	...	9	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	39·0	68·0	17	18·0	30	50·0	28·0	22·0	43·0	17	7·0	10	84·0	36·0	3·69	...	10	16	3	12	NW	W	W	Prof. J. A Stewart.
Bradford,	Wysox,	718	...	...	...	36·2	62·7	24	21·0	30	44·2	29·0	15·2	38·0	24	3·5	5	79·8	30·0	1·73	4·50	8	11	3	17	NW	NW	NW	Charles Beecher.
Bucks,	Forks of Neshaminy,	...	...	...	...	40·4	60·0	24	24·0	30	...	...	...	...	...	...	...	...	...	3·35	...	5	10	7	14	NW	NW	NW	
Bucks,	Point Pleasant,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Bucks,	Quakertown,	536	29·930	30·510	29·330	38·5	63·7	24	19·5	26	48·4	29·7	18·7	35·5	13	7·2	4	74·3	30·0	3·47	3·20	10	9	6	16	NE	NE	NE	J. L. Heacock.
Butler,	Butler,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
Cambria,	Johnstown,	1,184	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. C. Lorentz.
Cameron,	Emporium,	1,030	...	...	...	40·0	65·0	18	11·0	30	49·6	26·6	23·0	38·0	16	9·0	4	68·0	30·0	1·44	3·45	8	11	8	12	W	W	W	T. B. Lloyd
Centre,	State College— Agricultural Experiment Station,	1,191	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	32·8	67·0	18	13·0	30	44·4	27·0	17·0	40·0	17	5·0	10	...	...	2·27	2·25	13	9	10	12	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	29·913	30·503	29·341	40·1	63·5	13, 27	22·0	30, 31	40·4	32·1	8·3	31·0	31	5·0	21	66·0	29·6	5·44	3·00	15	11	8	12	NW	NW	NW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	39·8	67·0	13	21·0	26	51·3	30·6	20·7	40·0	13	7·0	4	...	...	4·49	2·96	14	9	9	13	W	W	W	W. T. Gordon.
Chester,[1]	Westtown,	550	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Clarion,	Rimersburg,	1,500	...	...	...	38·0	70·0	18	12·0	11	46·0	30·0	16·0	34·0	26	4·0	4	...	...	...	6·0	...	9	10	12	N	W	W	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion— State Normal School,	1,530	...	...	...	37·7	67·0	17	9·0	30	46·8	28·7	18·1	36·5	26	5·0	4	80·0	31·0	1·91	...	4	10	8	13	SW	SW	SW	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	36·6	66·0	18	12·0	30	45·4	30·0	15·4	32·0	26	2·0	5	...	...	2·57	7·00	12	12	5	14	W	W	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	39·2	69·0	17	19·0	26	49·0	28·0	21·0	43·0	17	6·0	10	...	...	2·63	3·50	8	11	6	14	W	W	W	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	40·7	65·5	24	23·0	30	50·5	33·5	17·0	32·0	18	5·0	4	...	...	2·99	3·50	7	10	9	12	N	N	N	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	41·3	68·	24	25·0	18, 30	51·1	34·4	16·7	36·5	26	2·0	19	71·0	31·8	1·91	...	9	9	8	14	N	W	SW	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	29·959	30·540	29·400	40·0	62·0	13, 24	23·0	30	47·7	34·0	13·7	28·0	13	4·0	20	75·4	32·2	3·26	..	9	7	9	15	NW	NW	NW	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore— Swarthmore College,	190	29·987	30·431	29·572	40·3	64·9	27	24·0	30	49·1	32·8	16·3	33·8	27	5·8	19	74·6	31·9	3·43	...	10	4	10	17	NW	NW	NW	Prof Susan J. Cunningham.
Erie,[1]	Erie,	681	29·980	30·450	29·470	34·0	58·0	27	20·0	11	40·0	29·0	11·0	24·0	15	3·0	8	73·0	27·0	1·73	4·00	10	11	12	8	NE	NE	NE	Peter Wood, Sgt Sig. Corps.
Fayette,	Uniontown,	1,000	29·960	30·364	29·510	41·5	68·0	18	11·0	11, 30	50·7	29·7	21·0	36·0	17	7·0	5	72·0	...	3·60	7·30	10	10	10	10	...	...	...	Wm. Hunt
Forest,	Tionesta,	1,058	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Robert L. Haslet.
Fulton,	McConnellsburg,	875	...	...	...	40·0	66·	24	22·0	30	51·9	31·1	20·8	37·0	13	5·0	21	75·7	31·2	4·76	...	10	11	9	11	NW	NW	W	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	...	...	...	38·9	65·	18	19·0	25	47·5	29·0	18·5	44·0	18	2·0	10	...	...	3·17	...	5	15	3	13	W	W	W	Prof. W J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	43·2	69·0	18	17·0	11	50·8	31·9	18·9	33·0	26	6·0	21	76·5	37·8	1·47	3·25	10	8	11	12	W	W	W	Prof. Albert E Maltby.
Lackawanna,	Scranton,	750	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. F. Baumeister.
Lancaster,	Lancaster— Franklin and Marshall College,	413	29·925	30·511	29·340	40·4	64·0	24	21·0	26	49·5	31·8	17·7	32·0	13	5·5	3	65·5	28·7	3·89	3·45	10	8	10	11	NW	W	NW	A. M. Schmidt, A.B.
Lawrence,	New Castle,	932	...	...	...	45·3	69·	17	9·0	30	51·0	25·0	26·0	40·0	17	7·0	21	88·2	41·5	2·73	2·50	5	12	4	15	NW	NW	NW	Wm. T. Butz.
Lebanon,	Lebanon,	480	29·915	30·523	29·347	38·4	65·	13	24·1	30	50·0	32·4	17·6	35·2	13	3·5	3	72·4	30·0	3·45	3·70	11	...	...	...	NE	W	NW	George W. Hayes, C.E., Ph G.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	35·8	61·	13, 27	15·0	30	47·8	28·8	19·0	33·0	14	8·0	4	...	...	2·61	...	5	6	14	11	..	...	...	H. D. Miller, M.D.
McKean,	Smethport,	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
Mercer,[1]	Greenville— Thiel College,	1,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	43·0	68·	13	24·0	30	50·6	34·6	16·0	36·0	13	4·0	19	71·7	34·5	3·73	1·00	7	14	6	11	NW	W	W	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Lerch & Rice.
Northumberland,	Shamokin,	733	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	G. R Hanley.
Perry,	New Bloomfield,	400	...	...	...	38·9	66·	17	19·0	26	48·7	29·9	18·8	38·0	18	2·0	19	...	...	3·91	2·00	8	8	6	17	W	W	W	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	29·941	30·530	29·360	41·1	66·	27	25·0	30	49·4	35·1	14·3	31·0	27	5·0	20	67·4	30·6	2·58	·50	12	11	5	15	NW	NW	NW	Luther M. Dey, Sgt. Sig Corps.
Potter,	Coudersport,	1,670	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. L. Peck.
Schuylkill,	Girardville,	1,000	29·955	30·469	29·426	38·8	61·0	18	19·0	30	46·5	29·9	16·6	40·0	31	6·0	4	...	...	2·77	8·00	8	16	6	9	NE	NW	NW	E C Wagner.
Snyder,	Selins Grove,	445	...	...	...	44·0	62·	13	24·0	30	49·3	39·7	9·6	28·0	17	3·0	20	77·0	33·4	2·60	2·50	5	12	8	11	NW	NW	NW	J. M Boyer,
Somerset,	Somerset,	2,250	...	...	...	35·3	65·0	17, 31	9·0	30	47·2	21·0	26·2	36·0	17	3·0	5	89·4	29·1	2·52	7·80	14	11	7	13	NW	NW	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	30·011	30·559	29·386	33·4	56·0	24	10·0	30	[illegible]	25·5	14·8	25·0	25	3·0	21	64·6	22·3	1·85	9·60	6	8	9	14	SW	NE	NE	E. S. Chase.
Tioga,	Wellsboro,	1,327	29·923	30·466	29·307	35·7	65·	17	18·0	30	45·6	28·9	16·7	36·4	30	5·2	5	80·6	26·3	3·24	3·00	8	10	7	14	N	N	N	H. D. Deming.
Venango,	Franklin,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. N. P. Kinsley.
Warren,	Columbus,	1,410	29·992	30·560	29·589	36·5	76·0	17	4·0	11	47·0	26·0	21·0	46·0	17	2·0	8	...	...	1·63	...	9	10	9	12	NE	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	33·3	59·	24	11·0	12	42·7	25·9	16·8	35·0	24	4·0	4	...	...	1·74	5·50	7	6	6	19	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	34·2	56·	24	15·0	12	41·6	26·8	14·8	30·0	12	4·0	20	...	...	1·88	...	10	...	...	...	...	...	...	John Torrey.
York,[1]	York,	385	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PRECIPITATION FOR MARCH, 1889.

	Erie.	New Castle.	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Indiana.	Somerset.	Grampian Hills.	Emporium.	Phillipsburg.	Huntingdon.	Hollidaysburg.	Altoona.	McConnellsburg.	Lock Haven.
1	·04	. .	. .	·05	·05	. .	·02	·10	. .	·25	. .	. .	·18	. .	. .	. .
2	·17	. .	·22	·34	·33	·75	·45	·20	·22	·04	·06	. .	·23	·02	·21	·60
3	·38	·90	·38	·81	·60	·07	·20	·07	·45	·38	·53	·60	·68	·47	·53	·32
4	. .	. .	. .	·11	·70	. .	·10	·60	·73	·33	·72	1·31	1·06	·95	1·77	·73
5	. .	. .	. .	·01	·05	. .	·05	. .	. .	. .	·16	·14	. .	·08	·86	. .
6	. .	. .	. .	·01	. .	. .	. .	·15	. .	. .	. .	. .	. .	. .	. .	. .
7	. .	. .	·02	. .	·03	. .	. .	. .	·03	. .	·01	. .	·30	. .	. .	. .
8	. .	. .	. .	·02	. .	. .	·03	. .	. .	. .	·02	. .	. .	. .	. .	. .
9	·06	. .	·04	·01	·05	. .	. .	·05	·03	. .	. .	. .	. .	. .	. .	. .
10	·20	·20	. .	·11	·05	. .	10	·14	. .	. .	·05	. .	. .	. .	. .	. .
11	. .	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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18	. .	. .	. .	. .	·31	. .	. .	·19	. .	. .	. .	. .	. .	. .	. .	. .
19	. .	. .	. .	·16	·66	. .	·02	·29	·08	. .	·05	. .	·38	·14	·57	·05
20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·08	. .
21	·02	·33	·05	·10	·15	·28	·10	·32	·15	·06	·20	·62	·36	·13	·48	·24
22	. .	. .	. .	·02	. .	. .	·40	·06	·20	·07	·33	. .	·07	·14	·15	·21
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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26	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
27	·08	. .	·03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .
28	. .	. .	. .	·04	·40	. .	. .	·08	·03	. .	·01	. .	. .	. .	. .	. .
29	·10	·05	·15	·13	. .	. .	. .	·15	·05	·06	. .	. .	. .	. .	. .	·01
30	·04	. .	·01	. .	·22	. .	. .	. .	. .	. .	·06	. .	·13	·02	. .	. .
31	·64	1·25	·73	·39	. .	·81	. .	·12	·60	·25	·07	·50	·30	·42	·08	·47
	1·73	2·73	1·63	2·32	3·60	1·91	1·47	2·52	2·57	1·44	2·27	3·17	3·69	2·37	4·76	2·63

	New Bloomfield	Carlisle.	Wellsboro.	Harrisburg.	Selins Grove.	Wysox.	Eagles Mere.	Catawissa.	Girardville.	Lebanon.	Lancaster.	Drifton.	Reading.	Pottstown.	West Chester.	Westtown
1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	·35	. .	·10	·06	·16	·17	·73	·03	·15	·05	·03	. .	. .	. .	·01	. .
3	·50	. .	1·54	·66	·34	·30	. .	·50	·95	·71	·96	. .	·74	·75	1·02	. .
4	2·20	. .	·60	2·13	1·22	·49	·28	1·64	·95	1·75	1·71	1·32	1·42	1·45	2·35	. .
5	. .	1·40	·2	·05	·63	. .	. .	. .	. .	·14	·29	·44	. .	·25	·34	. .
6	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
7	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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9	. .	. .	. .	. .	. .	·04	·19	. .	·03	·02	. .	. .	. .	. .	. .	. .
10	. .	. .	. .	. .	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	·02	. .
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17	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·15	. .
18	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·02	. .
19	·20	·01	. .	·07	. .	. .	. .	. .	. .	. .	·07	. .	. .	. .	·10	. .
20	·04	·10	. .	·04	. .	·18	·30	·20	·10	. .	·03	·25	·21	. .	·28	. .
21	·25	·30	. .	·17	. .	·03	. .	·22	·40	·46	·54	·45	·62	·80	·64	. .
22	·12	·02	. .	·03	. .	. .	. .	. .	. .	·03	. .	. .	·18	. .	·16	. .
23	. .	. .	·40	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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27	. .	. .	·10	. .	. .	. .	. .	. .	. .	08	·06	. .	·34	·20	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·03	. .	·04	. .	·11	. .
29	. .	. .	·05	. .	. .	·50	·13	·05	·01	. .	. .	. .	. .	·10	. .	. .
30	. .	. .	. .	. .	. .	. .	. .	. .	. .	·02	·05	. .	·02	. .	·06	. .
31	·25	·08	·2	·04	·25	. .	·22	·35	·18	·17	·12	·15	·14	·18	·16	. .
	3·91	1·91	3·2	3·26	2·60	1·73	1·85	2·99	2·77	3·45	3·89	2·61	3·71	3·73	5·44	. .

	Coatesville.	Dyberry.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Neshamíny.	Germantown.	Point Pleasant.
1	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
2	·05	. .	·12	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	1·23	. .	·18	·47	·18	·54	. .	·26	. .	. .	. .	. .	. .	. .	. .
4	1·60	·75	·57	1·25	1·59	·94	. .	1·31	2·08	. .	. .	. .	. .	. .	. .
5	·23	. .	. .	·33	·23	·06	2·26	·12	. .	1·80	2·19	1·57	1·83	1·58	1·89
6	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
7	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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16	·04	. .	. .	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .
17	·01	·17	·28	. .	·03	·01	. .	·03	·36	·05	. .	·05	·03	. .	·09
18	. .	·11	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
19	·03	. .	. .	. .	. .	·05	. .	. .	. .	. .	. .	. .	. .	. .	. .
20	·17	·05	·18	·11	·30	·16	. .	. .	. .	. .	. .	. .	·02	. .	. .
21	·66	·17	·03	·69	·55	·54	·78	·69	1·13	1·13	1·26	·85	1·39	1·46	1·40
22	·08	. .	. .	·13	·34	·13	. .	. .	. .	. .	. .	. .	. .	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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27	. .	. .	. .	·12	. .	. .	·32	·07	. .	·05	. .	·10	. .	. .	. .
28	·12	. .	. .	·01	·04	·04	·04	·11	·27	·15	·11	·06	·08	·07	. .
29	. .	·14	·01	. .	. .	. .	·05	. .	. .	. .	·08	. .	. .	. .	·02
30	·10	. .	. .	·18	. .	·05	. .	·04	. .	·07	. .	·16	. .	·17	. .
31	·14	·35	·49	·18	·17	·05	·14	·11	·58	·10	·13	·19	. .	·06	·05
	4·49	1·74	1·88	3·47	3·43	2·58	3·59	2·74	4·42	3·35	3·77	2·98	3·35	3·34	3·45

T. F. T.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR APRIL, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 30, 1889.

TEMPERATURE.

The average temperature of the state for April, 1889, was 48°·7, which is 2° 2 above that of April, 1888, 46°·5, which is about normal. Determined from the mean of the daily maximum and minimum temperature, it was 49°·7, which is one degree higher.

The warmest period of the month was during the 19th and 20th, when the following temperatures were noted: Carlisle, 88°; Hollidaysburg, 84°; Emporium, 84°; Grampian Hills, 84°; Uniontown, 84°, and New Castle, 84°. The lowest temperatures were Charlesville, 14°; Somerset, 14°, and Uniontown, 17°. These occurred on the 7th.

Stations reporting the highest monthly means for the state during April were Selins Grove, 52°·8; Swarthmore, 52°·4; Bethlehem, 52°·4; and Carlisle, 52°·3. The lowest were Eagles Mere, 42°·3; Greenville, 44°·1; Wellsboro, 44°·2; Erie, 45°·0; Somerset, 45°·2, and Honesdale, 45°·2.

BAROMETER.

The mean barometric pressure, 29·99, is very nearly normal. The highest occurred on the 7th and 23d, and the lowest, 29·3, on the 27th. The latter was attended by heavy rains.

PRECIPITATION.

The precipitation averaged 4·50 inches, with a decided irregularity in its distribution. The greatest totals in inches were Wellsboro, 8·15; Girardville, 7·23, and Coatesville, 7·08. Most of the precipitation for the month

occurred from the 24th to the 29th, inclusive. Only a few stations report snow in measurable quantities. The following are notable exceptions: Charlesville, 5·20 inches; Rimersburg, 9 inches; Grampian Hills, 5 inches; McConnellsburg, 12 inches; Somerset, 12·50 inches, and Columbus, 6 inches. These amounts fell on the 6th.

WIND AND WEATHER.

The prevailing direction of wind was from the west. No violent wind storm of a general character passed over the state. The latter part of the month was characterized by heavy rain storms. Numerous frosts occurred without seriously damaging vegetation.

At the end of the month, grain, grass, fruits and foliage, were more advanced than usual at this season. Notwithstanding the absence of snow during the winter months, grain was not materially injured by freezing out.

Average number.—Rainy days, 11; clear days, 11; fair days, 8; cloudy days, 11.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Charlesville, 20th; Reading, 12th, 20th; Hollidaysburg, 12th, 24th; Quakertown, 12th, 20th; Emporium, 12th, 24th; State College, 11th, 12th, 24th; Phillipsburg, 11th, 12th, 20th, 24th; West Chester, 20th, 28th; Coatesville, 2d, 20th, 28th; Rimersburg, 12th, 24th; Grampian Hills, 12th, 20th, 24th; Lock Haven, 12th, 24th; Catawissa, 12th; Carlisle, 13th, 20th; Harrisburg, 12th, 20th; Swarthmore, 12th, 20th, 28th; Uniontown, 12th, 24th; McConnellsburg, 12th; Huntingdon, 3d, 12th; Lancaster, 12th, 2-th; New Castle, 12th; Bethlehem, 12th, 20th; New Bloomfield, 12th, 27th; Philadelphia, 12th, 20th; Girardville, 20th; Selins Grove, 12th; Somerset, 12th, 24th; Eagles Mere, 12th, 20th; Columbus, 19th, 24th; Dyberry, 12th, 20th; York, 20th.

Snow.—Charlesville, 6th; Hollidaysburg, 6th; Emporium, 6th; Phillipsburg, 3d, 6th; Rimersburg, 6th; Grampian Hills, 6th; Uniontown, 6th; McConnellsburg, 6th; New Castle, 5th; Greenville, 5th; Selins Grove, 5th; Somerset, 6th; Columbus, 6th; Dyberry, 4th; York, 6th.

Frost.—Charlesville, 7th, 8th, 9th, 14th, 23d; Reading, 5th, 14th; Hollidaysburg, 7th, 8th, 17th, 22d, 23d; Wysox, 1st, 2d, 3d, 5th, 6th, 7th, 8th, 9th, 11th, 13th, 14th, 15th, 16th, 17th, 18th, 22d, 23d; Quakertown, 5th, 11th, 14th, 15th, 23d; Emporium, 5th, 7th, 9th, 11th, 15th, 16th, 17th, 22d; Phillipsburg, 7th, 8th, 9th, 10th, 15th, 16th, 17th; Coatesville, 23d; Rimersburg, 5th, 10th, 22d; Grampian Hills, 22d, 23d; Lock Haven, 22d; Catawissa, 7th, 8th, 9th, 10th, 11th, 14th, 15th, 16th; Erie, 7th, 8th, 10th, 14th, 15th; Uniontown, 9th, 10th, 14th; McConnellsburg, 11th, 22d; Huntingdon, 7th, 8th, 9th, 11th, 14th, 16th, 22d, 23d; New Castle, 6th, 7th, 14th, 23d; Greenville, 22d, 23d; New Bloomfield, 23d; Philadelphia, 15th, 23d; Selins Grove, 7th, 8th, 9th, 10th, 11th, 14th, 15th, 16th, 22d, 23d; Somerset, 22d, 23d; Wellsboro, 14th; Columbus, 1st, 2d, 4th, 5th, 6th, 7th, 8th, 10th, 11th, 13th, 14th, 15th, 16th, 17th, 21st, 22d, 23d; Dyberry, 2d, 3d, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 13th, 14th, 15th, 16th, 17th, 22d, 23d; York, 5th, 11th, 15th, 23d.

Coronæ.—Huntingdon, 14th, 19th.

Solar Halos.—Charlesville, 9th, 11th, 15th, 19th, 30th; Eagles Mere, 11th, 22d.

Lunar Halos.—Charlesville, 9th, 14th; West Chester, 9th; Rimersburg, 14th; Greenville, 14th.

Parhelia.—Charlesville, 19th; Dyberry, 6th; Eagles Mere, 10th.

Auroras.—Rimersburg, 7th; Greenville, 9th; Eagles Mere, 7th.

Observers are particularly requested to measure and record the rainfall *each day*, instead of giving the total for each storm. Each day's record should be made complete. Also to forward their monthly reports not later than the 5th, so that the REVIEW can be published at an earlier date. Original entries should be made in the book (Form 1) furnished by the service, and not on loose slips of paper. This will avoid errors in transcribing. Those not furnished with addressed envelopes should address all communications to the Pennsylvania State Weather Service, Philadelphia, Pa.

Percentage of local verifications of weather and temperature signals as reported by displaymen for April, 1889:

Weather, 82 per cent.
Temperature, 86 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.

Displayman.	*Station.*
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for April, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Temperature. Maximum. Highest.	Temperature. Maximum. Date.	Temperature. Minimum. Lowest.	Temperature. Minimum. Date.	Temperature. Mean of Maximum.	Temperature. Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Total Snowfall During Month.	Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	Wind. Prevailing Direction. 2 P. M.	Wind. Prevailing Direction. 9 P. M.	Observers.
Allegheny,[1]	Pittsburgh,	847	29.985	30.480	29.450	50.8	83.0	19	25.0	6	61.2	43.5	17.7	38.0	23	3.0	28	63.5	37.8	3.62	...	13	6	12	12	NW	NW	NW	Oscar D. Stewart, Sgt. Sig. Corps.
Beaver,	Rochester,	821	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Smith Curtis.
Bedford,	Charlesville,	1,300	...	...	...	49.5	79.5	19	14.0	7	61.3	40.5	20.8	39.5	23	3.5	27	69.2	36.6	4.76	5.20	12	9	11	10	W	W	W	Rev. A. Thos. G. Apple.
Berks,[1]	Reading,	304	30.001	30.408	29.336	49.4	78.0	19	27.0	14	62.7	40.8	21.9	43.0	11	6.0	26	80.0	42.2	6.33	...	13	12	6	12	NW	NW	SW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	54.3	82.0	20	47.0	7	62.5	42.2	20.3	35.0	22	8.0	29	58.2	40.0	3.44	...	12	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	51.0	84.0	19	25.0	23	63.0	36.0	27.0	47.0	11	8.0	27, 28	83.0	45.0	4.07	...	12	14	8	8	W	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	...	...	...	47.0	81.0	19	22.0	23	57.9	36.4	21.5	41.0	23	5.0	4	75.9	40.0	3.78	...	11	9	4	17	NW	NW	NW	Charles Beecher.
Bucks,	Forks of Neshaminy,	...	...	...	...	50.5	80.0	19	34.0	14	...	...	...	...	...	...	...	...	...	4.68	...	6	14	8	8	W	W	W	J. C. Hilsman.
Bucks,	Point Pleasant,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Bucks,	Quakertown,	536	30.029	30.490	29.380	49.7	79.0	20	24.0	6	61.3	38.6	22.7	43.8	11	6.3	27	74.0	40.6	4.83	...	14	8	11	11	NE	NE	N	J. L. Heacock.
Butler,	Butler,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
Cambria,	Johnstown,	1,184	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. C. Lorentz.
Cameron,	Emporium,	1,030	...	...	...	51.6	84.0	19	21.0	8	62.1	34.0	28.1	47.0	23	11.0	30	65.4	39.2	3.66	...	10	12	7	11	W	W	W	T. B. Lloyd.
Centre,	State College— Agricultural Experiment Station,	1,191	29.988	30.493	29.335	49.0	81.0	19	25.0	14	58.2	40.7	17.5	37.0	11	7.0	26	83.3	41.5	3.65	...	13	8	8	14	W	E	E	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	45.8	81.0	19	22.0	7	60.0	34.9	25.1	42.0	17	8.0	28	...	...	6.09	...	15	11	7	12	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	29.970	30.467	29.238	51.2	77.0	20, 21	30.0	14	61.1	42.2	18.9	32.5	11	4.0	27	67.0	40.0	5.46	...	15	11	9	10	NE	NE	NW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	49.6	83.0	20	27.0	14	61.8	39.2	22.6	45.0	11	5.0	27	...	...	7.08	...	16	9	8	13	NE	W	W	W. T. Gordon.
Chester,[1]	Westtown,	550	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Clarion,	Rimersburg,	1,500	...	...	...	47.7	82.0	19	23.0	6	57.9	38.8	19.1	36.0	16	2.0	28	...	...	...	9.00	...	12	6	12	NW	W	W	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion— State Normal School,	1,530	...	...	...	47.2	79.5	19	21.0	14	58.5	33.9	14.6	46.0	23	6.0	28	73.7	39.2	2.09	...	...	10	8	12	SW	W	SW	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	47.8	84.0	19	26.0	5	58.0	43.3	14.7	40.0	23	2.0	28	...	...	4.61	5.00	14	13	6	11	SW	SW	SW	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	50.5	85.0	19	26.0	14	60.2	37.0	23.2	41.0	19	4.0	26	...	...	3.97	...	12	14	5	11	E	W	W	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	51.3	82.0	20	29.0	7, 8	63.0	41.7	21.3	37.0	11	5.0	25	75.0	43.2	4.42	...	10	12	8	10	NE	N	N	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	52.3	88.0	20	35.0	7	63.0	45.9	17.1	35.0	21	3.0	25	71.0	43.7	4.56	...	14	11	7	12	W	W	W	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	29.613	30.470	29.000	50.6	80.0	20	34.0	5, 14	60.2	43.3	16.9	31.0	11	5.0	25	74.3	42.0	3.96	...	13	6	12	12	N	N	N	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore— Swarthmore College,	190	...	...	...	52.4	77.0	21	29.8	5	63.5	43.1	20.4	38.1	11	6.8	26	74.9	43.7	3.51	...	8	...	...	...	NW	NW	NE	Prof. Susan J. Cunningham.
Erie,[1]	Erie,	681	30.010	30.540	29.410	45.0	83.0	19	28.0	6	52.0	38.0	14.0	36.0	23	3.0	1	74.0	36.0	3.64	...	14	9	10	11	W	W	W	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	29.984	30.354	29.435	50.8	84.0	20	17.0	7	61.6	38.4	23.2	40.0	24	2.0	16	...	...	4.47	...	10	14	5	11	SW	W	W	Wm. Hunt.
Forest,	Tionesta,	1,058	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Robert L. Haslet.
Fulton,	McConnellsburg,	875	...	...	...	51.5	82.0	20	25.0	7	63.7	40.9	22.8	38.0	11	7.0	27	68.1	40.7	5.28	12.00	11	11	9	10	N	W	W	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	...	...	...	50.0	81.0	19	26.0	23, 24	60.9	39.4	21.5	48.0	11	5.0	26, 28	...	...	4.42	...	13	8	14	8	W	W	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	62.1	82.0	6	38.0	2, 25	65.5	57.5	8.0	16.0	23	3.0	11	88.1	58.4	4.50	...	6	14	6	10	W	W	W	Prof. Albert E. Maltby.
Lackawanna,	Scranton,	750	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. F. Baumeister.
Lancaster,	Lancaster— Franklin and Marshall College,	413	29.967	30.447	29.259	51.7	81.5	20	28.0	14	61.8	40.8	21.0	40.5	11	6.5	5	70.2	41.6	6.54	...	12	8	8	14	NE	W	W	A. M. Schmidt, A.B.
Lawrence,	New Castle,	932	...	...	...	50.1	84.0	19	21.0	6	60.0	35.0	25.0	46.0	23	7.0	1, 28	87.4	47.1	6.06	...	8	11	5	14	NW	NW	NW	Wm. T. Butz.
Lebanon,	Myerstown,	474	29.917	30.415	29.225	50.0	82.0	20	27.8	5	63.0	41.1	21.9	33.7	19	6.2	26	79.4	43.7	5.47	...	13	11	8	11	W	W	W	Wm. H. Kline.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	47.1	76.0	21	11.0	28	60.9	37.6	23.3	32.0	16	11.0	28	...	...	5.89	...	9	10	8	12	..	..	...	H. D. Miller, M.D.
McKean,	Smethport,	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
Mercer,[1]	Greenville— Thiel College,	1,000	29.932	30.468	29.362	44.1	82.0	19	23.3	6	58.4	35.2	23.2	45.7	23	4.0	28	79.9	37.8	2.50	3.00	9	10	9	11	SE	NE	NW	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	51.0	79.0	19	32.0	14	62.0	44.0	18.0	43.0	11	2.0	26	68.0	41.0	6.15	...	9	12	11	7	E	W	W	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	...	...	...	52.4	82.0	20	28.0	5	62.7	42.2	20.5	39.0	11	6.0	26	65.5	40.0	4.29	...	8	14	6	10	W	W	W	Lerch & Rice.
Northumberland,	Shamokin,	733	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	G. R. Hanley.
Perry,	New Bloomfield,	400	...	...	...	50.1	83.0	20	27.0	16	62.3	37.0	25.3	42.0	11	7.0	28	...	...	3.88	...	12	11	7	12	N	N	W	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	29.984	30.490	29.270	51.6	78.0	21	34.0	14	61.6	44.8	16.8	29.0	11	5.0	27	68.2	40.6	3.17	...	14	6	8	16	NE	NE	NE	Luther M. Dey, Sgt. Sig. Corps.
Potter,	Coudersport,	1,670	...	...	...	47.1	78.0	19	19.0	6, 22	58.0	30.0	28.0	48.0	18	3.0	29	67.3	38.5	4.50	...	...	13	4	13	W	NW	NW	C. L. Peck.
Schuylkill,	Girardville,	1,000	29.980	30.388	29.354	49.8	78.0	20	23.0	8	59.1	38.5	20.6	37.0	8, 11	6.0	25, 27	...	...	7.23	...	11	14	6	10	NW	NW	NW	E. C. Wagner.
Snyder,	Selins Grove,	445	...	...	...	52.8	80.0	20	32.0	5	60.0	44.8	15.2	33.0	11	6.0	25	72.4	43.2	3.02	...	9	8	11	11	NE	NE	NW	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	45.2	72.0	24	14.0	7	63.2	27.2	36.0	38.0	12	5.0	27	89.0	42.0	4.55	12.50	10	11	7	12	NW	NW	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	29.989	30.507	29.356	42.3	74.0	20	24.0	14	52.7	34.9	17.8	32.0	9, 18	2.0	1	69.8	33.6	5.71	...	8	12	6	12	NE	NE	NE	E. S. Chase.
Tioga,	Wellsboro,	1,327	29.960	30.374	29.316	44.2	80.0	19	22.0	23	55.9	35.1	20.8	34.4	19	6.0	29	76.1	32.6	8.15	...	12	11	6	13	N	N	N	H. D. Deming.
Venango,	Franklin,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. N. P. Kinsley.
Warren,	Columbus,	1,410	...	...	...	45.5	82.0	19	20.0	14	58.3	32.7	25.6	52.0	23	4.0	30	...	...	3.24	6.00	12	11	7	12	W	W	W	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	45.8	79.0	20	19.0	23	57.0	34.3	22.7	44.0	11	3.0	27	...	...	4.55	...	8	11	6	13	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	45.2	77.0	20	22.0	23	55.1	35.3	19.8	40.0	11	4.0	28	...	...	5.55	...	10	...	...	...	...	...	...	John Torrey.
York,[1]	York,	385	30.020	30.371	29.371	50.2	82.0	20	31.5	14	63.1	41.3	21.8	40.0	11	5.0	13	72.4	41.9	3.91	...	13	17	6	7	NW	NW	NW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PRECIPITATION FOR APRIL, 1889.

Day	Erie.	New Castle.	Greenville.	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Indiana.	Somerset.	Grampian Hills.	Emporium.	Phillipsburg.	Huntingdon.	Hollidaysburg.
1	.28	.38	.34	.33	.36	.35	.40		.48	.35	.50	.65	.10	.30
2	.19			.18			.05			.11	.07	.07	.12	
3	.01		.12	.06	.17		.14		.20	.10	.05	.15		.14
4	.04			.03	.02							.05		
5	.02				.02									
6	.48	1.75	.34	.65	.70	.09	.09		.85	.64	.19	.74		.99
7														
8														
9														
10														
11	.10			.17	.02	.04							.06	.23
12	.42	1.05	.37	.29	.77	.96	.25		.65	.60	.22	.55	.18	.54
13			.07		.25	.85	.35		.28	.95		.74	1.65	.16
14														
15														
16														
17														
18														
19								.40						
20	.02			.01				1.80		.06				
21		.78						.24				.13		
22														
23														
24	.46	1.27	.49	.31	.64	.72			.47	.10	1.00	.19	.04	.24
25	.02				.18	.40			.22	.85	26	1.18	.90	.62
26						.23			.95			.23	.95	.41
27	.45		.51	.35	.35	.59	.33		.22	.32	.39	.62	.18	.35
28	1.12		.19	.70	.12	.24		.02	.22	.38	.86	.38	.15	.07
29	.03	.83	.07	.16	.02		.48	2.00		.15	.12	.40	.09	.04
30								.04				.01		
31														
	3.64	6.06	2.50	3.24	3.62	4.47	2.09	4.50	4.54	4.61	3.66	6.09	4.42	4.07

Day	Altoona.	Charlesville.	McConnellsburg.	Lock Haven.	State College.	York.	New Bloomfield.	Carlisle.	Wellsboro.	Harrisburg.	Selins Grove.	Wysox.	Eagles Mere.
1	.12	.45	.53	.32	.20	.10	.48	.40	.72	.59	.22	.27	.75
2	.10			.01	.17	.07	.06	.70	.08	.05	.18	.50	
3	.06	.17	.16	.15	.04	.10	.10	.20	.05	.18		.14	
4													
5													
6	.67	1.33	1.60		.12	.05		.36					
7													
8													
9													
10													
11		.02		.01	.06	.01	.10		.04	.01	.10	.12	.42
12	.20	.54	.70	.20	.37		.40	.05	.24	.02	.10	.37	1.04
13	.75	.20		.54	.60		.30	.70		.58	.81		
14													
15													
16						.01							
17						.06				.01			
18								.03					
19													
20						.05			.10	.10			
21								.50					
22													
23													
24	.20		.22		.10		.75	.03	.10			.02	
25	.70	.97	.61	.94	.63	.70	.70	.46	.56	1.04	.10	.46	
26	.07	.91	.86	.25	.12	1.40	.35	.42	.94	.34	.25	.35	
27	.45	.13	.32	.45	.46	1.30	.45	.26	1.86	.62	.66	.64	
28	.07	.02	.19	.65	.63	.05	.16	.31	3.36	.28	.30	.70	
29	.05	.01	.05	.43	.05	.01	.03	.14	.10	.14	.30	.21	3.50
30		.01	.04	.02									
31													
	3.44	4.76	5.28	3.97	3.65	3.91	3.88	4.56	8.15	3.96	3.02	3.78	5.71

Day	Catawissa.	Girardville.	Lebanon.	Lancaster.	Driftoo.	Reading.	Pottstown.	West Chester.	Westtown.	Coatesville.	Dyberry.	Coudersport.	Honesdale.
1	.44	.51		.75		.42	.95	.31		.43	.36	.40	.18
2	.02	.18		.12		.09	.06	.2		.22	.05	.10	.13
3	.08	.08		.12		.03		.1		.07			.11
4													
5													
6				.12						.02			
7													
8													
9													
10													
11	.24	.13		.03		.01	.05	.01		.02			
12	.85	.86				.13	.30			.01	.39	.30	.32
13		.16		.32		.45		.13		.27		.40	
14													
15													
16								.02		.01			
17				.04		.09		.08		.05			
18								.02		.01			
19													
20				.32		.33	.25	.07		.15			.24
21								.04					
22													
23													
24													
25	.80	1.47		1.97		2.25	1.60	.35		1.92		1.30	2.90
26	.67	1.20		1.73		1.45	1.60	2.88		2.89	2.00		.46
27	.70	.98		.73		64	.90	.81		.69	1.45	.30	.64
28	.60	.93		.29		.36	.44	.35		.31		1.10	.48
29	.02	.73				.08		.04			.30	.60	.09
30										.01			
31													
	4.42	7.23	. .	6.54	.	6.33	6.15	5.46	. .	7.08	4.55	4.50	5.55

Day	Quakertown.	Swarthmore.	Philadelphia.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Neshamin'y.	Germantown.	Point Pleasant.	Bethlehem.
1	.91	.43	.42		.76	.83	.70	.73	.45	.67		.94	.50
2	.10	.29	.21	.61	.09		.06	.03		.06			.05
3			.03		.03				.33		.69		
4													
5													
6													
7													
8													
9													
10									.75				
11	.01				.09			.05	.05				.11
12	.14		.02	.19			.09	.22	.22				.63
13	.19	.07	.08	.61	.26		.22			.18	.17	.27	
14													
15													
16										.07		.13	
17	.08		.04	.06		.14							.03
18	.01	.01	.01		.03		.19	.04	.05				
19											.05		
20	.05			.04		.63	.25	.38	.30			.25	.05
21	.02	.17	.20		.17					.27	.14		
22													
23													
24													
25	.25												.81
26	1.83	1.73	1.53										
27	1.01	.42	.44		2.19								
28	.22	.39	.17	4.70	.21	3.04	3.51	3.46	2.40	3.43	2.15	3.52	2.12
29	.01		.02	.01	.03			.01	.35				
30													
31													
	4.83	3.51	3.17	6.22	3.86	4.64	5.02	4.92	4.90	4.68	3.20	5.11	4.29

T. F. T.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR MAY, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1889.

TEMPERATURE.

The mean temperature for May, 1889, was 62°·0, which is one degree above the average.

The warmest period of the month occurred on the 9th, and the coldest on the 2d, 4th and 29th. Frosts were general throughout the state on these dates.

The highest temperatures reported were Carlisle, 96°; Hollidaysburg, 94°; Reading, 94°; Coatesville, 94°, and York, 94°. The lowest temperatures were Emporium, 25°; New Castle, 26°; Columbus, 26°, and Dyberry, 26°.

The highest mean monthly temperatures were Indiana, 68°·3; Annville, 66°·5, and Emporium, 64°·5. The lowest were Wellsboro, 55°·1; Columbus, 56°·0, and Dyberry, 56°·3.

From January 1st to May 31st, the temperature excess was 404° at Philadelphia, 231° at Pittsburgh, and 56° at Erie.

BAROMETER.

The mean atmospheric pressure was 29·97, which is normal. The range between the extremes was about seven-tenths.

The highest noted was on the 18th, and the lowest during the 11th. Neither were attended by any unusual atmospheric conditions.

The minor depression of the 31st, accompanied the heavy rainfall on that date.

PRECIPITATION.

The average rainfall over the state during the month was 5·91 inches, which is an excess of over two inches. Had it not been for the phenomenal rainfall of the 31st, there would have been a deficiency in the western and middle portions of the state. The largest totals in inches for the month were McConnellsburg, 12·41; Grampian Hills, 11·60; Charlesville, 11·07; Harrisburg, 9·51; Smethport, 9·21, and Selins Grove, 9·20. The excessive and unprecedented rainfall of the 31st, which caused disastrous floods, was at

Grampian Hills, 8·37 inches; McConnellsburg, 7·08 inches; Charlesville, 6·71 inches; Selins Grove, 6 inches; Emporium, 5·85 inches; Smethport, 5·50 inches; Hollidaysburg, 5·12 inches, and Harrisburg, 4·66 inches. In the southeastern portion of the state the fall was very light on this date, many stations reporting less than one-tenth of an inch.

From the 1st to the 10th there was a general absence of rain. From this time to the end of the month rains occurred almost daily at some stations.

WIND AND WEATHER.

The prevailing direction of wind was from the west, and the month may be characterized as warm and moist. Frosts were general from the 1st to the 4th, inclusive, and on the 29th, all of which considerably impaired growing crops and fruits.

The first thunder storm of the month occurred on the afternoon of the 10th, and was general throughout the state. The lightning and wind caused heavy damages in several places. In some sections hail-stones of large size fell in quite large quantities. The storm was from the northwest, and its approach was heralded by great banks of ominous looking clouds, which were violently agitated. At most stations the wind was of terrific force, and carried with it blinding and stifling clouds of dust, which fairly darkened the atmosphere. At Philadelphia a velocity of seventy-two miles was registered. Fortunately the great force was of short duration. With the bursting of the storm the temperature fell from ten to twenty degrees. At Philadelphia the self-registering barometer fell rapidly from 8 A. M. From 1.30 P. M. to 4 P. M. the fall was more decided. After the storm burst at 5 P. M. it rose one-tenth instantaneously. As a *dust storm* it was phenomenal in magnitude and intensity.

On the 31st, the central portion of the state was visited by one of the greatest rainfalls and floods ever known in this country for magnitude and destructiveness. Large sections were flooded, whole towns and cities were swept away, thousands of people drowned, and millions of dollars in property destroyed. It is estimated that from six to eight inches of rain fell in twenty-four hours over a large area of the central part of the state.

Extracts from the reports of observers, May 31st:

Grampian Hills.—From 11.40 P.M. 30th to 11.20 P.M. of 31st, 8·37 inches of rain fell. Six inches of rain fell in seven hours. Most destructive flood in Anderson's Creek on record. Wind east.

McConnellsburg.—Easterly winds. 5·45 inches of rain from 4 P.M. 30th to 4 P.M. 31st. Rain ceased midnight of 31st; 8·31 inches in thirty-two hours. Disastrous floods.

Charlesville.—South, southeast, and southwest winds. Heaviest rains in years; 6·71 inches from 9 P.M. 30th to 9 P.M. 31st. Storm began 3.15 P.M. 30th.

Selins Grove.—Southeast winds. Rain began 2.20 P.M. 30th; six inches of rain on 31st. Thunder in east at 3 P.M.

Harrisburg.—On the 31st and night of 1st, eight inches of rainfall in eighteen hours.

Emporium.—Rain began 9 P.M. 30th, ended 11.20 P.M. 31st. Total rainfall, 5·85 inches. Water twelve feet above low-water mark, and from two to three feet higher than flood of 1861.

Smethport.—Southeast winds. Rain from 11 P.M. 30th to 11 P.M. 31st. Total rainfall, 5·50 inches.

Hollidaysburg.—Strong southerly winds until about 4 P.M., then veered a little easterly and gradually subsiding. Measurements of rainfall by rain gauge, May 30th, from 4 P.M. to 9 P.M., ·39 inches; to 7 A.M. 31st, 2·11 inches; to 12 M., 3·49 inches; to 5.30 P.M. 4·23 inches; to 7 P.M. 4·97 inches; to 9 P.M., 5·51 inches; to 7 A.M. June 1st, 6·10 inches. Strong northwest wind at midnight, 31st.

Huntingdon.—The flood of history in the Juniata Valley. Water higher than ever before known; 5·41 inches of rain fell from 7 A.M. 31st to 2 A.M. June 1st; 6·57 inches from 4 P.M. 30th to 2 A.M. June 1st. Winds east and southwest.

York.—High winds from southwest; 3·19 inches of rain from early morn of 31st to early morn of June 1st. Crops badly damaged.

Carlisle.—Rain gauge overflowed. Growing grain injured. Heavy wash-outs and bridges washed away. Water higher than ever known. Southeast winds.

New Bloomfield.—Terrible rain, with thunder. East winds. Rainfall, 3·82 inches.

Annville.—A continued succession of cloud bursts. Strong southeast winds. Occasional thunder.

Quakertown.—A peculiar storm. Strong southeast winds. Upper clouds nearly stationary. Dark and threatening lower clouds, moving rapidly from south. Very little rain.

Coudersport.—Rain began 5 P.M. 30th, ended morning of June 1st. Total rainfall, 5·40 inches; highest water ever known in this section. Great damage done in Potter County. Wind south.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Charlesville, 10th, 14th, 20th; Reading, 10th, 14th; Hollidaysburg, 10th, 24th, 27th; Wysox, 14th, 31st; Falls of Neshaminy, 14th, 21st; Quakertown, 10th, 14th, 21st; Emporium, 10th, 14th; Phillipsburg, 10th; West Chester, 10th, 14th, 21st; Coatesville, 10th, 14th, 21st; Clarion, 10th; Grampian Hills, 10th, 27th; Carlisle, 10th, 13th, 15th; Harrisburg, 10th, 14th, 21st; Uniontown, 10th, 19th, 30th; McConnellsburg, 13th, 30th; Lancaster, 13th, 14th, 21st; New Castle, 22d; Myerstown, 10th, 27th, 30th; Greenville, 10th, 14th, 16th, 27th; Bethlehem, 10th; New Bloomfield, 10th, 21st, 31st; Philadelphia, 10th, 14th, 21st; Girardville, 10th, 21st, 30th; Selins Grove, 10th, 14th, 21st, 29th, 31st; Somerset, 10th, 13th, 19th, 27th, 31st; Wellsboro, 10th, 21st; Columbus, 10th, 16th, 19th, 27th; Dyberry, 10th, 14th, 20th, 21st; York, 10th, 12th, 21st, 31st; Marshall's Creek, 10th, 14th, 20th, 21st.

Hail.—Hollidaysburg, 10th; Quakertown, 10th; Grampian Hills, 10th, 27th; Uniontown, 10th; Lancaster, 21st; Myerstown, 14th; Greenville, 10th,

27th; New Bloomfield, 21st; Selins Grove, 10th, 21st; Somerset, 27th; Dyberry, 10th; Honesdale, 10th; York, 21st.

Frost.—Charlesville, 2d, 4th; Reading, 3d; Hollidaysburg, 1st, 2d, 4th; Wysox, 4th, 29th; Falls of Neshaminy, 3d, 4th, 5th, 6th; Quakertown, 2d, 3d, 4th, 23d, 24th, 29th; Emporium, 1st, 4th, 5th, 29th; Phillipsburg, 1st, 24th, 29th; West Chester, 2d; Coatesville, 2d, 3d; Grampian Hills, 1st, 2d, 29th; Carlisle, 2d, 4th; Uniontown, 4th; McConnellsburg, 2d, 3d, 4th, 5th; Huntingdon, 2d, 29th; New Castle, 1st, 2d, 29th; Myerstown, 2d, 3d, 4th; Greenville, 1st, 2d, 29th; Bethlehem, 4th; New Bloomfield, 2d, 4th; Girardville, 29th; Selins Grove, 1st, 2d, 3d, 4th, 5th, 28th, 29th; Somerset, 1st, 4th; Wellsboro, 1st, 2d, 3d, 4th, 5th, 6th, 9th, 29th; Columbus, 1st, 2d, 4th, 5th, 29th; Dyberry, 2d, 4th, 5th, 29th; Honesdale, 1st, 2d, 3d, 4th, 5th, 29th; York 24th; Marshall's Creek, 1st, 4th, 29th.

Coronæ.—Reading, 10th, 14th; Myerstown, 10th.

Solar Halos.—Charlesville, 1st, 2d, 6th, 7th, 16th, 24th; Wysox, 10th; Wellsboro, 6th; Dyberry, 1st, 13th, 29th.

Lunar Halos.—Reading, 10th; Coatesville, 10th; Grampian Hills, 6th; Lancaster, 10th; Somerset, 11th.

Percentage of local verifications of weather and temperature signals as reported by displaymen for May, 1889:

Weather, 83 per cent.
Temperature, 87 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.

Displayman.	*Station.*
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	Wind. Prevailing Direction. 2 P. M.	Wind. Prevailing Direction. 9 P. M.	Observers.
Allegheny,[1]	Pittsburgh,	847	29'950	30'230	29'620	61'6	90'0	10	37'0	2, 4	72'2	52'5	19'7	32'0	5	4'0	31	62'5	47'8	[illegible]	14	7	9	15	NW	NW	NW	Oscar D Stewart, Sgt. Sig. Corps.
Bedford,	Charlesville,	1,300	. . .	. . .	. . .	58'9	89'5	9	29'0	2	71'1	51'7	19'4	34'5	8	7'5	22	71'4	50'0	[illegible]	13	14	7	10	W	W	SW	Rev. A Thos. G. Apple.
Berks,[1]	Reading,	304	29'989	30'314	29'704	60 5	94'0	5	32'5	3	75'3	50'1	25'2	45'0	10	6'5	27	82'6	53'3	[illegible]	9	15	7	9	NW	NW	NW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	. . .	. . .	. . .	64'1	91'0	10, 18	36'0	2	74'4	54'8	19'6	29'0	18	8'0	31	55'1	48'0	[illegible]	[illegible]	. . .	. . .	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	. . .	. . .	. . .	63'0	94'0	9	27'0	2	74'0	46'0	28'0	50'0	8	8'0	13	75'0	53'0	7'43	13	14	10	7	. . .	. . .	. . .	Prof. J. A Stewart.
Bradford,	Wysox,	718	29'964	30'238	29'728	58'9	89'2	17	29'5	4, 29	71'3	46'5	24 8	44'0	5	5 5	22	74'6	50'0	[illegible]	10	9	6	16	NW	NW	NW	Charles Beecher.
Bucks,	Forks of Neshaminy,	. . .	. . .	. . .	. . .	62'0	87'0	10	44'0	3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	5'70	11	14	7	10	W	W	W	J. C Hilsman.
Bucks,	Quakertown,	536	29'980	30'330	29'660	60'7	89'5	9	30'5	3	73'2	47'9	25'3	42'5	8	8'7	27	81'0	55'1	5'45	12	14	9	8	SW	NW	NW	J. L. Heacock.
Cameron,	Emporium,	1,030	. . .	. . .	. . .	64'5	92'0	18	25'0	4	73'2	44'8	28'4	48'0	5	5'0	31	. . .	. . .	[illegible]	11	12	7	12	W	W	W	T. B. Lloyd
Centre,	State College—Agricultural Experiment Station,	1,191	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof Wm. Frear.
Centre,	Phillipsburg,	1,350	. . .	. . .	. . .	56'9	93'0	17	27'0	2	72'0	44'1	27'9	47'0	8	4'0	27	. . .	. . .	5'28	11	11	5	16	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	29'958	30'345	29'657	62'4	90'0	9	38'0	2	72'2	53'6	18'6	32'0	5	5'0	20	72'0	52'5	5'78	15	14	7	10	NW	NW	SE	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	. . .	. . .	. . .	60'0	94'0	9	34'0	3	74'7	50'1	24'6	43'0	8	7'0	20	. . .	. . .	[illegible]	14	15	6	10	W	W	W	W. T. Gordon.
Clarion,	Rimersburg,	1,500	. . .	. . .	. . .	62'0	91'0	9	35'0	3	71 0	54'0	17'0	26'0	8	5'0	19	. . .	. . .	. .	. . .	11	11	9	W	W	W	Rev W. W. Deatrick, A.M.
Clarion,	Clarion—State Normal School,	1,530	. . .	. . .	. . .	58'0	86'0	10, 18	28'0	2	66'2	43'6	22'6	44'0	15	7'0	10	72'0	49'0	4'59	9	10	13	8	SW	SW	SW	C M Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	. . .	. . .	. . .	59'6	90'0	9, 17	30'0	2, 29	70'6	49'8	20'8	38'0	6	4 0	31	. . .	. . .	11'60	12	8	12	11	W	W	W	Nathan Moore.
Clinton,	Lock Haven,	560	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. John A. Robb.
Columbia,	Catawissa,	491	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Robert M. Graham.
Crawford,	Meadville—Allegheny College,	1,050	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	R. B Derickson.
Cumberland,	Carlisle,	480	. . .	. . .	. . .	63'4	96 0	8	36'0	4	74'7	56'4	18'3	34'0	9	3'0	26	74'5	57'3	4'52	14	9	9	13	W	W	W	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	29'984	30'350	29'350	61'5	90'0	9, 10	40'0	4	71'9	53'5	18'4	35'0	8	5'0	27	72'0	51'6	9'51	12	4	19	8	W	W	W	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore—Swarthmore College,	190	29'958	30'324	29'676	62'3	89'9	10	37'5	22	76'0	51'1	24'9	36'6	30	6'5	27	87'0	58'0	5'84	9	7	4	20	NW	NW	NW	Prof Susan J. Cunningham.
Erie,[1]	Erie,	681	29'960	30'210	29'610	58'0	89'0	18	35'0	29	65'0	50'0	15'0	29'0	30	4'0	21	69'0	47'0	[illegible]	14	9	11	11	SW	SW	SW	Peter Wood, Sgt Sig. Corps.
Fayette,	Uniontown,	1,000	29'966	30'222	29'750	60'9	88 0	10	30'0	4	71'6	48'4	23'2	39'0	6	5'0	22	70'0	50'5	6'93	12	10	15	6	W	W	W	Wm Hunt.
Fulton,	McConnellsburg,	875	. . .	. . .	. . .	62'1	93'0	9	31'0	2	73'4	48'9	24'5	44'0	8	6'0	31	74'0	52'1	[illegible]	13	11	8	12	W	W	W	Thomas F. Sloan.
Huntingdon,	Huntingdon—The Normal College,	650	. . .	. . .	. . .	60'7	93'0	17, 18	28'0	2	71'4	46'0	25'4	46'0	8	3'0	22	. . .	. . .	7'18	13	9	15	7	W	W	W	Prof. W J. Swigart.
Indiana,	Indiana—State Normal School,	1,350	. . .	. . .	. . .	68'3	85'0	25	40'0	3	79'2	58'0	21'2	41'0	3	19'0	8	81'0	62'0	4'71	8	16	5	10	W	W	W	Prof. Albert E Maltby.
Lancaster,	Lancaster—Franklin and Marshall College,	413	29'976	30'281	29'708	62'5	91'0	9	36'0	2	72'9	46'0	26'9	38'5	8	7'0	27	82'6	57'1	4'16	12	10	11	10	W	W	SE	A. M. Schmidt, A B.
Lawrence,	New Castle,	932	. . .	. . .	. . .	61'8	90'0	9, 17	26'0	2	71'5	44'7	26'8	45'0	6	11'0	10	. . .	. . .	[illegible]	6	6	14	11	NW	NW	NW	Wm. T. Butz.
Lebanon,	Myerstown,	474	29'939	30'262	29'741	60'4	93'9	9	32'6	2	74'8	56'4	24'4	41'8	8	7'2	27	83'6	55'8	5 17	14	14	4	13	W	W	W	Wm. H. Kline.
Lebanon,	Anville—Lebanon Valley College,	339	. . .	. . .	. . .	66'5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	77'2	61'2	. .	. . .	15	7	9	. . .	. . .	. . .	Geo. W. Bowman, A.M , Ph.D.
Luzerne,	Drifton—Drifton Hospital,	1,655	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	.	. . .	. . .	. . .	. . .	. .	. . .	. . .	H. D. Miller, M.D.
McKean,	Smethport,	1,500	. . .	. . .	. . .	57'4	89'5	18	27'0	4	69'3	44'1	25'2	44'5	8	7'5	2	. . .	. . .	[illegible]	8	11	10	10	S	S	S	Armstrong & Brownell.
Mercer,[1]	Greenville—Thiel College,	1,000	29'865	30'138	29'569	56'3	87'4	10	27'0	2	70'8	44'4	36'4	39'5	5	8'0	31	84'9	49'8	[illegible]	10	5	7	10	SW	SW	SW	Prof S. H. Miller.
Montgomery,	Pottstown,	150	. . .	. . .	. . .	63'0	91'0	10	36'0	3	74'3	55'3	19'0	35'0	7	. . .	27	75'0	53'0	7 47	9	17	9	5	W	W	W	Charles Moore, D.D.S.
Monroe,	Marshall's Creek,	520	. . .	. . .	. . .	58'7	75'1	17	42'1	2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	73'5	55'5	[illegible]	11	10	11	10	W	W	W	Harvey Huffman.
Northampton,	Bethlehem,	360	. . .	. . .	. . .	64'0	92'0	9	34'0	4	74'0	51'0	23'0	45'0	6	8'0	27	66'0	52'0	[illegible]	10	17	6	8	W	W	W	Lerch & Rice.
Perry,	New Bloomfield,	400	. . .	. . .	. . .	62'1	93'0	9	29'0	4	74'6	46'3	28'3	48'0	6	6'0	31	. . .	. . .	6'06	12	11	9	11	W	W	W	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	29'982	30'380	29'650	63'0	90'0	9, 10	43'0	2, 3	74'1	55'3	18'8	33'0	9	4'0	27	71'4	53'0	4'32	15	8	11	12	NW	NW	NW	Luther M. Dey, Sgt. Sig Corps.
Potter,	Coudersport,	1,670	. . .	. . .	. . .	59'7	90'0	17	26'0	29	69'4	44'5	24'9	46 0	8	7'0	3	78'9	54'3	7'90	8	10	3	18	NW	W	W	C. L. Peck.
Schuylkill,	Girardville,	1,000	29'964	30'314	29'609	60'0	89'0	9	33'0	2	70'7	49'3	21'4	40'0	5	7'0	20	. . .	. . .	6'93	12	12	2	17	NW	NW	NW	E. C Wagner.
Snyder,	Selins Grove,	445	. . .	. . .	. . .	63'2	92'0	9, 10	40'0	3, 4	71'3	55'2	16'1	36'0	5	4'0	27	. . .	. . .	9'20	10	13	8	10	NW	SE	NW	J. M Boyer.
Somerset,	Somerset,	2,250	. . .	. . .	. . .	54'2	92'0	17	28'0	2	68'3	44'6	23'7	44'0	7	11'0	25	. . .	. . .	8'32	9	14	5	12	NW	NW	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	. . .	. . .	. . .	57'3	86'0	10	31'0	2	64'7	48'7	16 0	27'0	29	3'0	21	70'0	47'5	9'21	10	10	8	13	SW	SW	SW	E. S. Chase.
Tioga,	Wellsboro,	1,327	29'932	30'258	29'622	55'1	90'0	17	30'0	29	79'9	67'2	11'7	20'0	. .	5'2	. . .	78'9	42'3	3'45	10	12	9	10	N	W	N	H. D. Deming.
Warren,	Columbus,	1,410	. . .	. . .	. . .	56'0	92'0	17, 18	26'0	1, 29	68'9	43'3	25'6	48'0	8	3'0	21	75'0	47'0	2'65	15	11	9	11	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	. . .	. . .	. . .	56'3	88'0	9	26'0	4	69'3	44'4	24'9	44'0	6	3'0	27	. . .	. . .	4'72	15	10	9	12	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	. . .	. . .	. . .	56'4	83'0	17	28'0	4	67'5	45'2	22'3	38'0	5	4 0	27	. . .	. . .	5'47	12	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
York,[1]	York,	385	29'977	30'216	29'728	63'2	94'0	9	35'0	2, 4	74'9	30'9	44'0	42'0	5	9'5	27	70'0	52'5	5'65	10	17	7	7	NW	NW	NW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PRECIPITATION FOR MAY, 1889.

Date	[illegible]	[illegible]	New [illegible]	Columbus.	Pittsburgh	Uniontown	In[illegible]	Somerset.	Grampian Hills	Empo[illegible]	Philipsburg	Hu[illegible]	Ho[illegible]	Altoona	Cha[illegible]	McC[illegible]	Lock Haven	New [illegible]	Car[illegible]	W[illegible]	Ha[illegible]	Selins Grove.	Wysox.	Eagles Mere.	Catawissa.	Girardville	Meyerstown	Lancaster
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9							·15																					
10		·20	1·05	·17	·03				·31	·44			·3			·17				1		·16	1	·4				
11		·14		·11	2·27			1·20	·48			·15				·52												
12				·04																	·14							
13				·01	·45	·41			·34	·40	·34					·12			·45	·14		·70	·10			1·05		
14	·20		·52		·35	·25	·1		·31	·09	·24								·47					·42			·43	·51
15					·1																						·01	
16				·12																								
17																												
18																												
19	·29		·25			1·34			·41	·50					·06						·17		·11	·51		·48		·19
20													·04			·33							·8	·90		1·03	·94	·78
21									·05		·02				·01	·05					·21		·07	·82				·38
22			·15						·11		·08		·07								[illegible]	·15				·07	·14	
23														·06		·07											·01	·11
24					·47																							
25											·17		·04					·16								·07	·07	·03
26															·1			·44								·18	·34	·67
27				·47	·04					·15		·30						·44					·27	·48		·91		·83
28				·01																							·01	
29																												
30				·07						·1								·37				·46		·36		·61	·67	
31				·74	1·21			1·43	·37						·71									5·17				·5
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4·71	[illegible]	[illegible]	8·04	[illegible]	[illegible]	7·43	4·75	[illegible]	12·41		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4·76	[illegible]		6·93	5·47	4·46

Date	Drifton	Reading	Bethlehem.	Pottstown.	West Chester.	Kennett Square	Coatesville.	[illegible]	[illegible]	Swarthmore	Ph[illegible]	[illegible]	Schultzville.	Frederick	[illegible]	Smith's Corner	Doylestown	La[illegible]	[illegible] Ne[illegible]	Germantown	Point Pleasant	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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15						·15	·01																			
16																										
17																										
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19			·64			·17	·34																			
20			1·54	1·50	1·76		1·03						·4	·57			·04									
21			·05			·24	1·0																			
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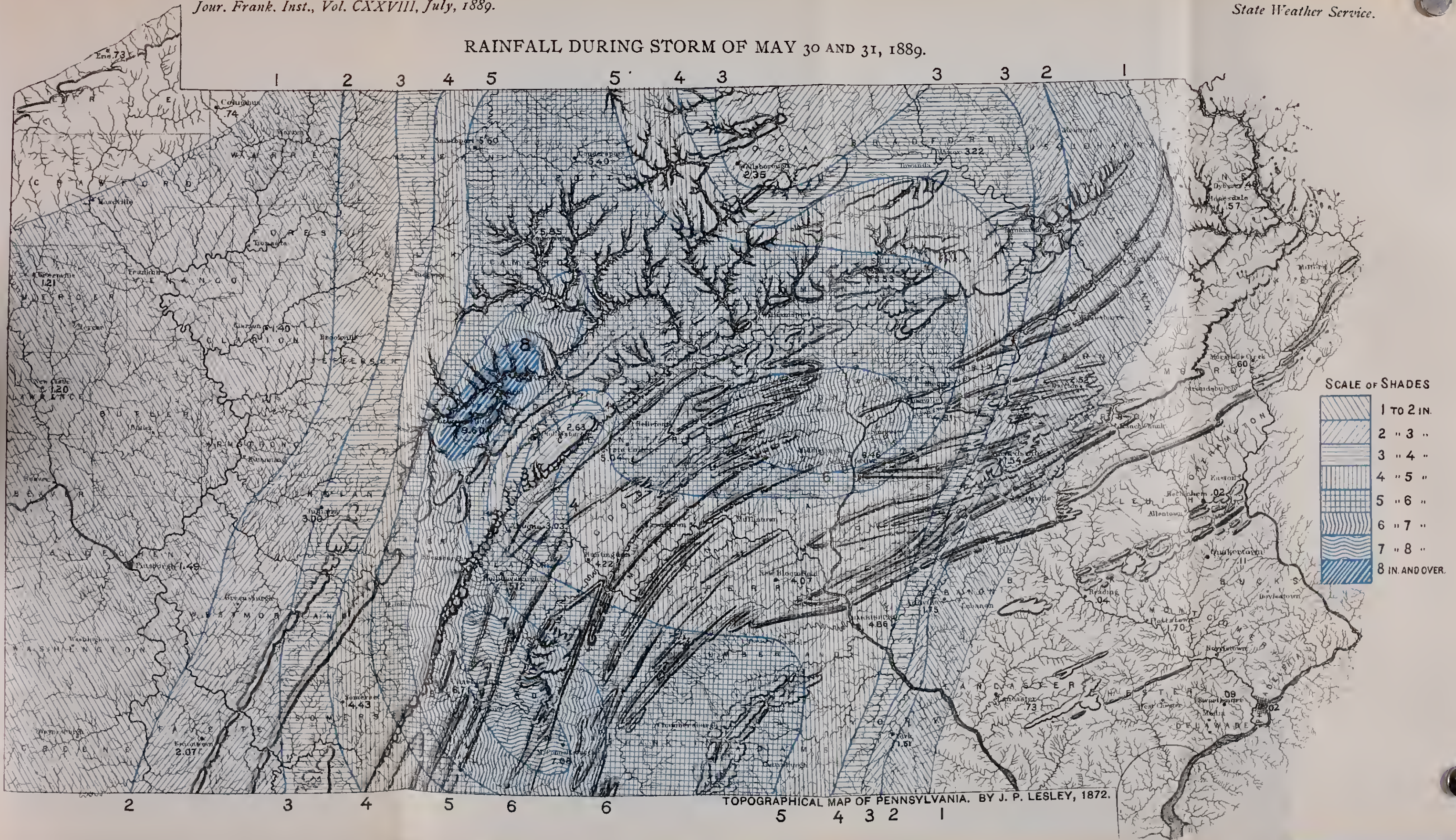
24																										
25			·36											·04												
26						1·32																				
27							·84							·91						·14						
28																										
29																										
30																										
31		·04		1·70																						
Total		3·60	[illegible]	7·47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

T. F. T.

RAINFALL DURING STORM OF MAY 30 AND 31, 1889.



PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR JUNE, 1889.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 30, 1889.

TEMPERATURE.

The mean temperature for the month of June, 1889, was 66°·5, which is from two to three degrees below the average, and two degrees below the corresponding month of last year.

The means of the daily maxima and minima were 76°·4 and 57°·0, respectively.

Neither extreme high nor low temperatures were noted during the month.

The warmest period at most stations was on the 21st, and the coldest on the 2d, 7th and 24th. Frost occurred in some of the northern border counties on these dates.

The highest recorded temperatures were: Reading, 95°; Carlisle, 93°; Pottstown, 91° and York, 91°.

The lowest were Dyberry, 33°; Honesdale, 35°, and State College, 37°.

BAROMETER.

The mean pressure was 0·06 above the normal. The greatest pressure was on the 24th, and the least on the 5th. The extreme range was about 0·75.

PRECIPITATION.

The average rainfall for June, 1889, was 5·43 inches, which is an excess of 1·63 inches.

The entire month was characterized by frequent and heavy rainfalls. The great and destructive rain-storm of the 30th and 31st of May continued to the morning of June 1st over a great extent of country. On the last-named date, over twenty stations report a fall of from one to three inches, making a total in inches for the three days' storm, as follows: Wellsboro, 9·80; McConnellsburg, 8·99; Grampian Hills, 8·60; Harrisburg, 7·78; Selins Grove, 7·53; Charlesville, 7·50; Huntingdon, 6·57; Coudersport, 6·33; Phillipsburg, 6·09; Smethport, 6·00; New Bloomfield, 6·14; Emporium, 5·97; Hollidaysburg, 5·80; Eagles Mere, 5·53; Altoona, 5·33; Girardville, 4·59; Somerset, 4·43; Myerstown, 3·37.

For the month of June, 1 station had rain on 21 days, 4 stations on 20 days, 1 station on 19 days, and 3 stations on 18 days. The average for the state was 15 days.

The following stations report the greatest total in inches: Wellsboro, 10·04; Myerstown, 8·66; Reading, 8·21; Girardville, 8·01; Scisholtzville, 7·91; Ottsville, 7·58; Smith's Corner, 7·54; Uniontown, 7·36; Quakertown, 7·31, and Harrisburg, 7·18.

The excessive rainfall, and the unusual number of rainy days, marks the month as exceptionally wet. With the exception of the 2d, 23d and 24th, rain fell on every day in some part of the state.

WIND AND WEATHER.

The prevailing winds were from the west and southwest, with no severe and general gales. A few frosts were reported, but no damage of any amount resulted from them. The month was excellent for the growth of all vegetation, and large crops were secured where harvesting was not interfered with by the excessive wet.

In some sections the damage to the hay crop was very great.

Average number.—Rainy days, 15; clear days, 5; fair days, 12; cloudy days, 13.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Charlesville, 4th, 11th, 14th, 16th, 21st, 28th; Reading, 4th, 5th, 9th, 11th, 15th, 17th, 21st, 29th, 30th; Hollidaysburg, 14th, 21st; Quakertown, 9th, 11th, 15th, 17th, 21st, 29th; Emporium, 21st, 30th; State College, 4th, 21st, 28th; Phillipsburg, 15th, 21st; West Chester, 5th, 10th, 15th, 17th, 21st; Coatesville, 5th, 10th, 15th, 17th, 21st, 30th; Rimersburg, 14th, 19th, 21st, 27th, 30th; Carlisle, 9th; Harrisburg, 17th; Swarthmore, 5th, 10th, 11th, 14th, 15th, 21st, 30th; Uniontown, 14th; Huntingdon, 4th, 11th, 15th, 17th, 28th; Indiana, 11th; New Castle, 4th, 17th, 27th; Myerstown, 5th, 9th, 11th, 15th, 17th, 21st; Smethport, 21st; Greenville, 17th, 30th; Pottstown, 4th, 15th; New Bloomfield, 4th, 9th, 15th, 21st; Philadelphia, 4th,

11th, 15th; Coudersport, 21st, 28th; Girardville, 4th, 9th, 28th, 29th; Selins Grove, 4th, 9th, 10th, 15th, 21st, 29th; Somerset, 4th, 16th, 19th; Wellsboro, 15th, 21st, 28th; Columbus, 15th, 16th, 17th, 20th, 21st; Dyberry, 9th, 11th, 15th, 16th, 21st, 29th; York, 11th, 17th, 21st.

Hail.—Dyberry, 15th.

Frost.—Phillipsburg, 24th; Wellsboro, 23d, 24th; Dyberry, 7th; Honesdale, 7th.

Coronæ.—Charlesville, 4th, 11th, 12th; Reading, 15th, 17th; Somerset, 8th, 9th.

Solar Halos.—Charlesville, 21st, 24th, 29th; Reading, 4th, 15th; Pottstown, 4th; Wellsboro, 19th; Dyberry, 3d, 19th, 25th.

Lunar Halos.—Charlesville, 10th; Rimersburg, 9th; Carlisle, 9th, 10th; Indiana, 8th; Wellsboro, 20th.

Auroras.—Greenville, 20th; Girardville, 23d; Selins Grove, 23d.

WEATHER FORECASTS.

Percentage of local verifications of weather and temperature signals as reported by displaymen for June, 1889:

Weather, 76 per cent.
Temperature, 88 per cent.

TEMPERATURE AND WEATHER SIGNAL DISPLAY STATIONS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.

Displayman.	*Station.*
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
Smith Curtis,	Beaver.
M. Tannehill,	Confluence.
S. C. Burkholder,	Pollock.
Robt. M. Graham,	Catawissa.
Henry F. Bitner,	Millersville.
A. J. Edelman,	Pottstown.
A. M. Wildman,	Langhorn.
N. E. Graham,	East Brady.
B. F. Gilmore,	Chambersburg.
Frank M. Morrow,	Altoona.
A. Simon's Sons,	Lock Haven.
E. W. McArthurs,	Meadville.
J. K. M. McGovern,	Lock No. 4.
Raftsman's Journal,	Clearfield.
W. S. Ravenscroft,	Hyndman.
R. C. Schmidt & Co.,	Belle Vernon.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for June, 1889.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Temperature. Maximum. Highest.	Temperature. Maximum. Date.	Temperature. Minimum. Lowest.	Temperature. Minimum. Date.	Temperature. Mean of Maximum.	Temperature. Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	Wind. Prevailing Direction. 2 P. M.	Wind. Prevailing Direction. 9 P. M.	Observers.
Allegheny,[1]	Pittsburgh,	847	30'004	30'420	29'720	67'3	87'0	21, 30	46'0	2	76'1	60'4	15'7	24'0	7	7'0	1	70'4	56'8	4'93	18	1	8	21	SW	SW	SW	Oscar D Stewart, Sgt. Sig. Corps.
Bedford,	Charlesville,	1,300	...	...	...	64'8	86'5	21	43'0	24	76'1	58'7	17'4	29'5	24	9'0	11	81'8	59'3	4'26	15	5	12	13	W	SW	W	Rev. A Thos. G. Apple.
Berks,[1]	Reading,	304	30'043	30'399	29'721	67'8	95'0	20	44'0	7	80'9	58'9	22'0	34'0	21	5'0	11	85'1	62'6	8'21	16	11	7	12	NW	...	SW	C. M. Dechant, C.E.
Blair,[2]	Altoona,	1,181	...	...	...	69'6	88'0	22	47'5	2	79'2	60'1	19'1	26'5	18	11'0	19	62'5	56'0	4'73	17	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	66'0	90'0	21	40'0	2	78'0	53'0	25'0	43'0	8	10'0	12	83'0	62'0	2'71	20	5	19	6	SW	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	30'010	30'466	29'659	69'0	87'5	21	39'0	7	76'7	55'0	21'7	38'0	7	6'1	12	82'2	60'0	4'86	16	7	7	16	SE	SW	NW	Charles Beecher.
Bucks,	Forks of Neshaminy,	...	...	...	...	66'5	82'0	21	54'0	7	...	...	...	...	...	...	...	...	...	4'49	11	4	18	8	W	W	W	J. C. Hilsman.
Bucks,	Quakertown,	536	30'030	30'450	29'570	67'2	87'5	21	40'0	7	79'0	56'1	23'9	35'7	7	14'7	5	86'5	63'7	7'31	17	4	15	11	SW	SW	SW	J. L. Heacock.
Cameron,	Emporium,	1,030	...	...	...	68'2	90'0	21	38'0	7	77'7	53'9	23'8	39'0	21	2'0	5	74'8	60'0	4'63	12	4	16	10	E	W	W	T. B. Lloyd
Centre,	State College— Agricultural Experiment Station,	1,191	29'977	30'385	29'629	64'9	85'0	21	37'0	2	73'9	52'4	21'5	31'0	21	14'0	5	83'2	59'9	5'37	15	3	13	14	W	W	W	Prof. Wm. Frear.
Centre,	Philipsburg,	1,350	...	...	...	62'4	88'0	29, 30	38'0	2	75'3	53'1	22'2	35'0	24	11'0	5	...	...	5'84	20	3	9	18	SW	SW	SW	Geo. H. Dunkle.
Chester,	West Chester,	455	30'024	30'446	29'643	68'9	86'5	21	48'0	7	77'5	61'2	16'3	26'0	7	10'0	5	75'0	60'5	5'38	19	11	14	5	S	SW	SW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	68'7	89'5	20, 21, 28	42'0	7	80'1	58'6	21'5	35'0	7	12'0	30	...	...	5'99	15	10	12	8	W	S	W	W. T. Gordon.
Clarion,	Rimersburg,	1,500	...	...	...	68'2	86'0	29, 30	47'0	1	74'1	61'7	12'4	25'0	21	2'0	5	...	...	...	18	6	11	13	SE	SW	S	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion— State Normal School,	1,530	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	64'5	88'0	21	48'0	1, 2	75'0	60'0	15'0	28'0	24	6'0	5	...	...	3'71	17	3	10	17	W	SW	SW	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof John A. Robb.
Columbia,	Catawissa,	491	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R. B. Derickson.
Cumberland,	Carlisle,	480	...	...	...	69'1	93'0	21	50'0	2	78'5	63'1	15'4	31'0	20	2'0	12	84'4	64'0	4'59	17	5	14	11	S	S	S	J. E. Pague.
Dauphin,[1]	Harrisburg,	361	30'054	30'480	29'690	67'4	87'0	21	50'0	2	76'8	60'2	16'6	26'0	13	3'0	12	76'6	59'4	7'18	20	5	15	10	E	E	E	Frank Ridgway, Sgt. Sig. Corps.
Delaware,	Swarthmore— Swarthmore College,	190	30'016	30'436	29'655	69'3	87'2	20	46'2	5	78'1	59'8	18'3	32'5	8	10'9	10	78'5	63'0	5'48	10	3	8	19	SW	SW	SW	Prof Susan J. Cunningham.
Erie,[1]	Erie,	681	30'007	30'460	29'680	64'0	82'9	9	45'0	1	70'0	57'0	13'0	22'0	9	4'0	22	76'0	56'0	6'02	8	3	9	18	SE	SE	SE	Peter Wood, Sgt Sig. Corps.
Fayette,	Uniontown,	1,000	30'022	30'332	29'740	67'8	87'0	21	44'0	2	76'2	58'1	18'1	30'0	24	6'0	1	79'0	61'5	7'36	21	7	19	4	W	W	W	Wm Hunt.
Fulton,	McConnellsburg,	875	...	...	...	66'2	87'0	21	40'0	7	77'6	57'2	19'4	36'0	7	5'0	19	78'1	58'2	5'17	15	8	13	9	W	W	W	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	...	...	...	65'2	89'0	29	38'0	2	75'1	54'6	20'5	35'0	7	8'0	12	...	...	5'60	16	5	10	15	W	W	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	67'9	87'0	21	44'0	23	76'5	58'2	18'3	29'0	21	10'0	26	80'2	61'0	3'39	13	4	8	18	SW	W	SW	Prof. Albert E Maltby.
Lawrence,	New Castle,	932	...	...	...	68'7	87'0	29	38'0	6	77'1	53'3	23'8	35'0	7	15'0	11	...	...	6'50	9	3	4	23	SE	SE	SE	Wm. T. Butz.
Lebanon,	Myerstown,	474	30'014	30'722	29'654	66'3	87'4	20	43'0	7	78'9	58'4	20'5	34'0	7	11'2	12	90'0	63'8	8'66	13	7	18	5	W	W	W	Wm. H. Kline.
Lebanon,	Anville— Lebanon Valley College,	339	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Geo. W. Bowman, A.M., Ph.D.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	63'6	86'0	21	44'0	8	75'9	55'0	20'9	34'0	8	10'0	5	...	...	4'99	11	4	16	10	...	...	...	H. D. Miller, M.D.
McKean,	Smethport,	1,500	...	...	...	67'4	88'0	30	38'0	25	75'8	52'0	23'8	37'0	25	6'0	11	80'0	61'0	5'93	13	4	14	12	S	S	S	Armstrong & Brownell.
Mercer,[1]	Greenville— Thiel College,	1,000	29'954	30'390	29'642	63'5	87'0	30	41'5	1	73'7	54'8	18'9	32'0	24	9'9	22	...	...	3'51	10	5	5	20	SW	SW	SW	Prof S. H. Miller.
Montgomery,	Pottstown,	150	...	...	...	71'3	91'0	21	53'0	24	78'9	64'0	14'9	28'0	21	3'0	5	76'5	62'0	6'20	10	13	11	6	W	W	W	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	...	...	...	70'2	88'0	21	46'0	7	79'1	60'0	19'1	35'0	8	7'0	25	73'0	61'0	5'28	...	...	...	...	...	...	...	Lerch & Rice.
Perry,	New Bloomfield,	400	...	...	...	66'2	90'0	20	40'0	19	74'2	54'2	20'0	38'0	9	12'0	12	...	...	6'25	13	5	12	13	S	SE	SE	Frank Mortimer.
Philadelphia,[1]	Philadelphia,	117	30'050	30'460	29'680	69'8	88'0	20, 21	54'0	6, 7	79'4	63'3	16'1	22'0	20	10'0	12	74'0	60'8	3'39	13	2	13	15	SW	SW	SW	Luther M. Dey, Sgt. Sig Corps.
Potter,	Coudersport,	1,670	...	...	...	65'2	86'0	20, 21	35'0	7	75'4	48'8	26'6	41'0	20	11'0	1	80'4	60'4	4'80	11	7	6	17	W	W	W	C. L. Peck.
Schuylkill,	Girardville,	1,000	30'052	30'457	29'716	66'0	85'0	21	47'0	7	75'7	56'0	19'7	33'0	8	11'0	12	...	...	8'01	15	10	12	8	W	W	W	E. C. Wagner.
Snyder,	Selins Grove,	445	...	...	...	68'2	85'0	16, 30	55'0	6, 7	75'7	63'0	12'7	20'0	24	6'0	5	...	...	5'10	14	3	15	12	SW	SE	SE	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	60'4	83'0	21	41'0	1, 23	73'6	54'4	19'2	30'0	24	7'0	22	...	...	3'87	14	6	11	13	SW	SW	SW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. S. Chase.
Tioga,	Wellsboro,	1,327	29'973	30'463	29'608	63'3	86'0	10, 29	42'0	24	74'2	55'2	19'0	9'5	24	3'0	5	...	...	10'04	20	4	12	14	S	SW	SW	H. D. Deming.
Warren,	Columbus,	1,410	30'121	30'576	29'802	63'2	90'0	30	38'0	6, 7, 24	73'8	52'6	21'2	40'0	24	8'0	11	80'2	55'6	5'12	18	4	9	17	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	63'0	85'0	30	33'0	7	74'0	52'0	22'0	40'0	7	11'0	12	...	...	4'24	11	5	14	11	W	W	W	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	63'7	82'0	10, 29	35'0	7	73'7	53'7	20'0	36'0	7	9'0	1	...	...	3'13	12	...	...	...	...	...	...	John Torrey.
York,[1]	York,	385	30'036	30'489	29'745	66'5	91'0	21	49'0	1, 2, 24	79'8	59'6	20'2	33'0	7	5'0	25	72'2	59'4	5'13	13	15	8	7	SW	SW	SW	Mrs. L. H. Grenewald.

[1] Observations taken at 8 A. M. and 8 P. M. [2] Observations taken at 12 Noon.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PRECIPITATION FOR JUNE, 1889.

Day	Erie.	New Castle.	Greenville.	Columbus.	Pittsburgh.	Uniontown.	Clarion.	Indiana.	Smethport.	Somerset.	Grampian Hills	Emporium.	Phillipsburg.	Huntingdon.	Hollidaysburg.	Altoona.	Charlesville.	McConnellsburg.	State College.	York.	New Bloomfield.	Carlisle.	Wellsboro.	Harrisburg.	Selins Grove.	Wysox.
1	.14	1.05		.34		.04			.50				3.26	1.75	39	2.30	.18	.68	1.94	1.70	2.07	1.50	7.45	3.12	1.07	.14
2																										
3	.04				.04	.21			.20	.50			,01	.12	.12		.29	.35	.05	.18					.06	.35
4	.04	1.50		.05	.44	.06			.50		.20	.25	.02	.96	.05	.03	.13	.45	.64	.46	.90	.52	.10	.30	.63	.57
5	.03			.12	.08	.21			.70		.03	.22	.02		.02	.03			.05	.50		05	.12	.32	.34	.15
6	.02			.08						.02						.02										
7	.08	.30		.10		.02		.18	.40						.05								.05			.15
8	.90			.97	.10	.43		.01	.30		.30	.60	.45	.15	.01	.03		.17	.22		.14	.20	.08	.08	.05	.20
9	.24			.12	.06				.40			.16	.08										.05			
10	.02				.02	.23		.10	.10	.23	.25	.20	.20	.04	.14	.05	.08		.08		.06	.05	.12	.20	.17	
11		.35	.17	.15	.90	.10		.90	.60		.30	.18	.12	.38	.30		.15	.15	.15	.47	.52	.05	.16	.24	.31	.32
12					.08	.21		.25		.30	.18		.20	.12	.13	.57	.15	.17	.15	.20	.10	.11	.06	.12	.10	.01
13						.01								.01								.01				
14	.04		.32	.02	.08	.29		.10		.15				.01	.40		1.93	.86				.08				.02
15	.32	.50	.23	.51	1.73	.51		.70		.17	.98	.92	.24	.68	.19	.33	.04	.3[illegible]	.29	.16	.33		.25	.75	.21	.12
16	.99		.62	.50	.04	.27		.02		.25	.06		.05		.02	.15			.19	.05		.03				.80
17	2.15	.57	1.19	.92	.12	1.14			.85	.35	.16	1.02	.16	.31	.02	.03	.20	.41	.80	.15	.29		.65	.31	.29	.52
18											.20		.25		.01	.10						20	.10			
19	.10		.04	.11	.31	.26		.10	.30	.88		.11	.02	.10	.09	.02	.06	.05	.04				.05	.02		.04
20	.10			.25		.27					.06		.01			.34										
21	.14	.78	.20	.13	.20	.78		.28	.75	.30		.47		.40	.29		.11	26	.97	.10	.81		.42	.18	.30	.95
22											.45		.35			.44				.80		.73		.10		
23																										
24																										
25			.10	.08	.32	1.25		.40		.30				.05	.06		.15	.13		.01	.08	.05	.10	.04	.10	.41
26	63		.46	.65	09	.12		.45	.33	.20	.16	.45	.26	.07	.29	.23	.26	.20	.18	.35	.80	.65	.15	.50	.85	.11
27	.04	.65	.18	.02	.21					.03	.26	05	.01		.01	.04					.01	.02		.06		
28		.80			.02	.67				.09			.05	.45			.50	.43	.12		.14	13	.08	.12	.62	
29						.28					.02		.08		.12		.03	.56				.15		.72		
30								.10			.10					.02							.05			
31																										
Total	6.02	6 50	3.51	5.12	4.93	7.36		3.39	5.93	3.87	3.71	4.63	5.84	5.60	2.71	4.73	4 26	5.17	5 87	5.13	6.25	4 59	10.40	7.18	5.10	4.86

Day	Girardville.	Myerstown.	Drifton.	Reading.	Pottstown.	West Chester.	Coatesville.	Dyberry.	Coudersport.	Honesdale.	Quakertown.	Swarthmore.	Philadelphia.	Scisholtzville.	Frederick.	Ottsville.	Smith's Corner.	Doylestown.	Lansdale.	Forks of Nesham'y.	Germantown.	Point Pleasant.	Bethlehem.
1	3.05	1.62	.36	2.01	1.00	1.20	1.07	.71		.25	.95	.58	.46	1.93	.98	.19	1.02	.68	1.67	.70		.44	1.00
2																							
3	.02					.03	.02				.03		.02			.15	.04				.04		
4	.99	.15	.76	.03	.60	.03	.10	.09	.30	.14	.04	.02			.09	.13	.06			.03		.01	.22
5	.07	.31		.52		.25	.25	.30	[illegible]	.34	.16	.34	.20	.33	.30		.10	.24		.14	.09	.01	
6																							
7																							
8	.06	.09	.11	.04		.03		.32	.10	.37	.04			.48	.05	.05				.01			
9		1.01		.01				.05		.07	.11			.63		.17	.03	.90		.55		.05	.04
10		.02				.26	.20		.10										.11				
11	.50	.76	.34	.85	.70	.18	.10	.50	.10		.44			.72	.32	.84	.31	.26	.22	.20		1.10	.97
12	.19	.13	.12	.11	.20	.81	.30			.02	.35	.60	.43	.10	.33	.12	1 02	.99	.34		1.16	.05	.68
13						.03				.22	.02	.12			.15					.70			
14						.30	.14					.68	.04										
15	.36	.16	.10	.53	1.17	.65	1.60	.53	.30		1.63	.72	.54	.78	1.75	1.18	.76	.56	.92		.54	.50	.71
16						.09		.37	.30		.41				.77					.16	.04	.25	
17	.47	1.67	.48	.99	.10	.32	.30	.41	.80	.61	1.05		.05	.51		.40	.80	.53			.14	.84	.04
18						.04	.02				.07		.01										
19																			.19				
20				.01																			
21	.27	2.68	.35		.35	.02	.03	.25	2.00	.41	.04		.01	.75	.22	.22	.21	.11		.10		.15	44
22		.01	.10	.65		.11	.45				.14	.13	.06										
23																							
24																							
25	.21			.03	.85	.03			.20							1.00							
26	1.11		2.06	1.27	1.00	.94	1.11	.71	.50	.76	1.55	2.25	1.35	1.68	1.30	.90	2.04	1.55	2.10	1.37	1.35	1.75	1.78
27			.21							.01						.01							
28	.09			.05												.30							
29	.56	.05		.99							.25					1.88	1.15			.53		.17	
30	.06			.12	.23	.06	.11					.04	.22		.15	.04							
31																							
Total	8.01	8.66	4.99	8.21	6.20	5.38	5.99	4.24	4 80	3.13	7 31	5.48	3.39	7.91	6.41	7.58	7.54	5.82	5.45	4.49	3.36	5 32	5.28

T. F. T.